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ABSTRACT

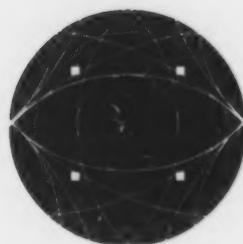
The public sector in Finland faces tasks and challenges in promoting science, technology, and innovations in conditions of global change. Sustainable economic, social, and cultural development will continue to demand comprehensive development of the innovation system based on solid cooperation between the public and private sectors in the country. A special challenge for the public sector is to be able to implement the necessary development measures simultaneously in all directions under conditions of international competition and cooperation. Conditions must be created for the development of information industries, especially by strengthening human resources. The overall level of education must be further raised in Finland, and postgraduate education must be strengthened. It is also necessary to promote the utilization of knowledge produced both abroad and in Finland. In addition, the public sector must develop research funding to promote science, technology, and innovation. Three appendixes report the accomplishments of the Science and Technology Policy Council from 1996-1999; record the interim accomplishments of the expert group as of December 10, 1999, and report on the development of sectoral research. (KC)

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Science and Technology Policy Council of Finland

Helsinki 2000

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Summary

The review "*The Challenge of Knowledge and Know-how*" of the Science and Technology Policy Council focuses on the tasks and challenges of the public sector in promoting science, technology and innovations in conditions of global change. As a result of this change, the tasks of the public sector have grown and become more demanding; the measures taken by it are an important element in response to future challenges.

Sustainable economic, social and cultural development will continue to demand comprehensive development of the innovation system based on solid cooperation between the public and private sectors. Alongside quality, efficiency and relevance, the focus is on impact and impact analysis. It is important to carry on the internationalisation of the innovation system.

Challenges for the public sector

A special challenge for the public sector is to be able to implement the necessary development measures simultaneously in all important directions in conditions of international competition and cooperation.

There must be input into creating conditions for the development of the information industries. The development potential inherent in the software and content industries must be systematically utilised. Special attention needs to be paid to strengthening human resources.

Development measures based on the promotion of knowledge and know-how and their utilisation must be continued within all sectoral policies, with a growing emphasis on cooperation. In regional development and in labour and environmental policies, this approach must be particularly pronounced. For the public sector, the promotion of social and cultural development is just as demanding and challenging as its responsibilities in the field of economic development.

Measures are needed to identify and systematically develop new growth areas. Creating general conditions conducive to business development entails development of venture capital and business know-how and the promotion of entrepreneurship and an enterprise culture.

Education and research must be continuously strengthened. This task is particularly demanding in view of the rapid growth in knowledge-intensive industries. The dissemination of existing knowledge and know-how over sectoral and branch boundaries must be intensified. Another important task is to develop a regionally comprehensive innovation network.

Development of knowledge and know-how

The overall level of education must be further raised in Finland. It is important to be able to improve the matching of education and working life. The response to changing knowledge needs among the adult population must be in keeping with the principles of lifelong learning and investment in it. The most urgent of all the special measures needed is to increase basic mathematical and scientific knowledge and to widen the recruitment basis in higher education.

Efforts must be made to improve basic conditions for university research and postgraduate education with a view to strengthening research environments and developing their material resources. It is the task of the Academy of Finland to step up and expand measures for increasing high-standard research and expertise. Finland must ensure its readiness to respond to global transitions in the economy, culture and science e.g. by means of science watch and technology foresight.

In sectoral research, the uncommitted research funds at the disposal of ministries must be evaluated. Cluster-based activities must be further developed, and the networking model developed within it should also be applied to other research programmes. The structural development of sectoral research must be continued as part of the overall reform of the central administration.

The National Technology Agency (Tekes) must promote the spread of knowledge-intensive growth into new areas, step up its measures for securing conditions for domestic growth in R&D and enhance its competence in response to the new challenges.

Utilisation of knowledge and know-how

It is necessary to intensify the utilisation of knowledge produced both abroad and in Finland with a view to distributing the positive effects of growing research and education to benefit society and citizens as widely as possible.

Tekes, jointly with other partners, must promote the dissemination and utilisation of knowledge and know-how, for instance by developing high-standard expert services. Public and private investors must take joint action to improve access for new enterprises to venture capital.

Polytechnics must be developed into knowledge and know-how centres which serve innovation in their regions more extensively than at present. EU structural funds must be used in the regions to generate knowledge and know-how and promote their large-scale utilisation. The activities and resources of employment and economic development centres must be channelled so that they promote development and creation.

Business enterprises must improve their capacity for the economic utilisation of their own innovation processes and innovations. It is a task for the public sector to increase the supply of expertise and know-how, among other ways by developing business training and other educational provision. The growth potential of business should be a central criterion in public promotion measures.

Development of research funding

The public sector must be able to develop research funding under its competence in an appropriate manner. Additional input is needed both to generate knowledge and know-how and to intensify their utilisation.

Public research funding needs to be increased cumulatively by EUR 200 million over the 2001–2004 period. Such an increase is justified in relation both to the tasks of the public sector in science, technology and innovation policies and to the development of private R&D funding and the capacity of the state finances. The funding programme requires careful monitoring and impact analysis in support of future policy lines and development measures.

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Preface

The long-term development line in Finnish science, technology and innovation policies is characterised by determined input into R&D, a balanced development of the national innovation system as a whole and strengthening contacts between the different policy sectors.

The fifth triennial review of the Science and Technology Policy Council carries on this development line in a globalising environment. The change in Finnish societal and industrial structures remains rapid, and a response must be found to this challenge. The review presents the Council's recommendations for development over the next few years. International cooperation is not addressed separately; the relevant opinions are integrated into the review.

The most important science, technology and innovation policy decision during the term of the previous government concerned an increase in government research funding by EUR 250 million over the 1997–1999 period. This has been achieved in the 1999 budget in the manner proposed by the Science and Technology Policy Council. The impact of the additional funding is currently being assessed; the relevant interim report is appended to this review.

In its programme, the Finnish Government appointed in April 1999 reaffirms the policy line geared to strengthen knowledge and know-how. According to this programme, the future of Finland and Finns is strongly dependent on know-how, an ability to utilise know-how and create new

innovations. Raising the level of know-how among the whole population will improve Finnish competitiveness and benefit Finnish civilisation.

The Government foresees that R&D will continue to expand. Alongside R&D, the intention is to improve the quality of activities and intensify the transfer and utilisation of research findings. Increasing attention will be paid to the services sector. The knowledge and know-how network will be strengthened through the establishment of a comprehensive innovation network.

In university and basic research, the Government will especially focus on securing core funding, developing creative research environments, supporting high-standard research in all disciplines, and carrying on the policy of centres of excellence. Apart from the Government programme, another topical policy statement is the development plan for education and university research 1999–2004, which was adopted on 29 December 1999.

Answers to future challenges are being sought in different forums. Finnish science and technology policy and the operation of the national innovation system are currently being evaluated by means of several studies and reviews. Reviews and programmes which support the information society development, studies on globalisation and foresight carried out within the Government and Parliament are important projects outlining and influencing the future of society as a whole. They help to provide a clearer picture of future development needs relating to knowledge and know-how and to target public measures better and thus improve their effectiveness.

1

Public sector as promoter of science, technology and innovation

Since 1990, the Science and Technology Policy Council has examined the promotion of science, technology and innovations from the point of view of *the national innovation system* in a wide sense. The national innovation system is a domain for interaction in the production and utilisation of knowledge and know-how built on cooperation between all producers and utilisers of new knowledge. The development of the innovation system rests heavily on close cooperation between the public and private sectors. Networking is a key element in the development of activities and organisations.

The globalisation of the economy and technology has introduced new elements into development. Rapid technological change is closely linked with the integration of the international capital market. As was noted in an extensive study on globalisation undertaken by Sitra (the Finnish National Fund for Research and Development), great fluctuations are a permanent feature of the world economy. No agreement has been reached on new rules of the game which would bring more stability. Both business enterprises and the public sector must prepare themselves for a long transition period.

The impact of globalisation does not work only one way. According to the Sitra study, this impact is largely dependent on internal factors in society, such as people's competence, technological development, regional policy, ageing or cultural elements. Global developments highlight the need for smoothly-running and effective national and regional innovation systems as increasingly important factors for economic growth and social welfare. Advanced industrial countries are involved in a process of moving on from a resource-based economy to a knowledge-based economy. In Finland the change in the industrial structure has been rapid. Knowledge and know-how in their different forms, as well as their efficient production, dissemination and utilisation are thus of key importance in societal development.

Marked changes create a need to strengthen the knowledge base in support of decision-making. Measures to this end include the intensification of innovation research and international comparisons. These show that Finland has so far fared well in the ongoing global change. Finland has been able to capitalise on the opportunities opened up by knowledge-intensive growth to an exceptional degree. Characteristically, Finland has been able to develop the entity of knowledge and know-how production and utilisation – i.e. the innovation system in a wide sense – on a long-term basis. The Science and Technology Policy Council has consistently been of the opinion that the innovation system must ensure the availability of knowledge and know-how needed in economic, social and cultural development and create conditions conducive to their efficient use. One important challenge is to develop cooperation between environmental policy and the innovation system.

On the basis of innovation studies it is possible to draw the following conclusions concerning the development of the Finnish economy, employment and industrial structure:

- R&D provides a basis for knowledge-intensive growth – without continual input the prerequisites of growth will gradually deteriorate,
- Knowledge-intensive growth has significant employment effects,
- The fact that economic growth is innovation-driven has a major impact on regional growth,
- Knowledge-intensive growth has been business-driven.
- Conditions favourable for knowledge-intensive growth are created within different policy sectors; in an innovation- and knowledge-

based economy, cooperation between different sectors is a requisite, as is cooperation with the national innovation system.

The growth in corporate research for its part has shown that innovations are increasingly created in cooperation between business and industry, research organisations and other public sector. It is important that business enterprises, universities and research institutes, as well as the public administration function fluently and efficiently. Of primary importance, however, is how efficiently and well they work *together*. Change highlights the role of the public sector as a comprehensive maintainer and developer of the national innovation system. It is essential to be able to identify and understand the most important development targets in the system and to put right shortcomings in its operation.

The limited resources at the disposal of the public sector have led to a shift in general strategic thinking from input-driven to efficiency-driven growth strategies. From the viewpoint of a knowledge-intensive economy, the task of the public sector is to maintain a stable macro-economy and create an operational environment conducive to innovation. The measures to this end include competition policy, the dismantling of unnecessary regulation and subsidies, enhancement of the labour market and the liberalisation of international trade.

Another task for the public sector is to maintain and develop a regulatory and administrative structure which encourages innovation. This includes education and training, research and innovation and their public funding, the development of financing markets which promote innovation, and other measures in support of structural change.

Innovation studies have also thrown new light on the role of the public sector in the ongoing knowledge-intensive change in business. Access to a highly trained work force and necessary know-how, the accumulation of human capital, norms and standards, international rules of the game, competition setting, and a climate favourable to business are examples of the areas where business enterprises need input from the public sector. In addition to general measures, there are problems specific to the SME sector relating to financing, management, marketing and technological know-how which have to be addressed.

The public sector's field of operation is thus wider and more demanding than before. The set of prerequisites which can, and should, be influenced by public measures involve most policy sectors. The growing significance of lifelong learning and learning organisations in turn highlights social and

organisational innovations as key socio-economic development factors. New innovation research supports the line of action adopted in Finland for comprehensive development of the national innovation system. By its determined participation in the development, the public sector also helps effectively to reduce non-anticipated consequences. These may include unexpected environmental effects or social segmentation and the threat of exclusion. The principles of sustainable development are an inherent element in development.

The measures taken by the public sector are not generally sector-specific, influencing one sector only. Science and technology policy is not mere "research promotion" or "technological development", policy measures are intended to influence, and do influence, society as a whole. Change based on innovation and knowledge means that the rationale behind the development of government research financing no longer stems from a traditional input-driven strategy.

The Science and Technology Policy Council has systematically promoted the dissemination and adoption of this holistic view in Finland. The development of the national innovation system has created conditions for the growth of knowledge and know-how as well as their extensive utilisation to benefit society and the individual. It is, however, necessary to constantly develop the system and to put right shortcomings identified e.g. in the economic utilisation of research findings.

From the viewpoint of society, the foremost aims in the development of the innovation system are culture, welfare, and intellectual growth, as well as a balanced development of the economy, employment and the environment at the national level and in different parts of the country. The foremost priorities in the internal development of the system are still to improve quality, efficiency and relevance. Strong development demands are directed at education, research, knowledge-intensive business and international cooperation.

Measures are still needed in the innovation system to develop and deepen its cooperation and interaction with other policy sectors. Knowledge and know-how are opening up new opportunities for finding solutions to the problems of the economy, society and the individual. This alone does not, however, suffice; the full utilisation of these opportunities and their positive effects is in many ways linked to measures carried out within other policy sectors. One of these is development of the information society.

2

Present situation and challenges

The foregoing stresses that the smooth operation and development of the national innovation system is based on good cooperation between the public and private sectors. There are many examples of this in Finland. One is the information industry, which is discussed in more detail in 2.1. Another is research funding in general. As a result of systematic efforts, the relative research input has gradually grown, being now over three per cent of the gross domestic product (GDP). In quantitative terms, research input doubled during the seventies, eighties and nineties. It has been possible to carry out development in a way which has strengthened all parts of the research system. Business enterprises, the university sector and research institutes are all at a top world level as regards their research volume in relation to GDP. The balanced development of financing, which is a result of a cooperative effort, is a great asset. The quality, relevance and international visibility of research have steadily improved.

It is vital that this positive development continues. Input into the development of information industries must continue to be a clear priority in education, science and technology policies. It is a major challenge for a

small country to sustain this achieved strength under conditions of rapid growth.

It is just as important to be able to develop other key fields side by side with information industries. The demand for good cooperation between different policy sectors not only concerns the development of an innovation- and knowledge-based economy and necessary social, organisational and institutional conditions. Such cooperation equally serves other social and cultural development. Education, research and technological development are strategic resources in efforts to solve development problems and construct the information society.

The traditional Finnish strengths – forest and metal industries – were surpassed during the nineties by electric and electronic industries, which invest heavily in R&D. The structural change towards an industrial and services structure increasingly based on knowledge and know-how must be continued: it is necessary to find new growth areas in addition to current strengths and to enhance the prerequisites of business enterprises operating in them. Global interest is particularly directed at the bio-sector and knowledge-intensive services. It is also necessary to be able to apply extensively in other fields knowledge and know-how already accumulated, especially generic telecommunications know-how. This too entails cooperation between the public and private sectors.

The foregoing demands a determined, comprehensive effort to develop the knowledge and know-how infrastructure. The foundation for immaterial and material welfare is built by means of education and research. It is necessary to keep creating new knowledge and know-how throughout the education and research system, and transfer them flexibly to social, economic and cultural development and make them available to citizens. The knowledge base must be continually strengthened to enable it to be utilised on a sustainable basis in the future. The development of university activities and their prerequisites is one key factor in this.

The public sector will have specific development tasks in all the directions described above. These tasks and challenges are discussed separately in the following.

2.1

Promotion of information industries

The change in industrial structure in Finland over the past three decades has been exceptionally rapid even in international terms. The change continued during the 1990s at an accelerating pace. Production based on electronics and information and communications technologies (ICT) and the export of relevant products have grown more rapidly than predicted. Overall production in the branch increased fivefold over the 1990s, and the production of "telecommunications hardware and consumer electronics" has grown fifteenfold.

Whereas in 1970 the electric and electronics industries represented two per cent of Finnish exports as a whole, the corresponding figure was 11 per cent in 1990 and 29 per cent in the first half of 1999. Similarly, the balance of trade in high-tech products has changed remarkably rapidly. In 1990 the exports corresponded to about half of the imports, to the tune of EUR one billion. In 1998 the exports already amounted to EUR 7.2 billion, exceeding imports by EUR 2.35 billion.

There are many reasons for the change. For the first time in its history Finland finds itself on the crest of innovation, albeit in a fairly narrow field. The ongoing "wave of innovation in digital networks" is based on extensive development and utilisation of ICT. This has long been a priority in Finnish technology and innovation policies, indeed the basis on which a humane information society is built.

The progress made so far can with good reason be considered as a result of a national project. About two thirds of Finnish R&D is currently carried out in business enterprises. The rapidly growing share of the electric and electronic industries now represents over half of all private sector R&D, and is still growing. As research directly or indirectly serving information industry is also conducted in universities and public sector research institutes, it can be estimated that about half of all the national research input is used in or for the benefit of this single branch. In terms of money this amounted to some EUR 1.7 billion in 1998. In higher education the proportion is nearly the same: some 35 per cent of all the university and polytechnic graduates have an education in ICT or neighbouring fields.

Pooling of resources of this magnitude would not have been possible without good cooperation between the public and private sectors. One example of this is the programme for increasing education in information

industry fields over the period 1998–2002, to which business enterprises in the field make a substantial contribution. According to the programme, intake into higher education will be increased both permanently and temporarily by means of the retraining of technology graduates and additional training, which are efficient and rapid ways to increase availability of competent personnel.

The challenge is to be able to keep up the positive trend in telecommunications equipment and step up developments in other electric and electronic industries (computers and electronic office equipment, electric power engineering). The anticipated growth in the information industries in the near future is expected to go along the same lines as in the 1990s as regards production, exports and jobs. Thus there are several reasons why production should stay in Finland. Over 30 per cent of the employees in the electric and electronic industries work within R&D. This makes constant demands especially on the qualitative and quantitative development of higher education. One well-known problem is that the recruitment base is narrowing for two reasons: the extent of mathematical and scientific knowledge in secondary education and training (both as regards the number of proficient people and the level of knowledge) is insufficient and the number of people over 20 who apply for higher education will start decreasing as the polytechnic system gradually reaches its full extent. In 1997 the number of new students in polytechnics and universities was over 45,000 and the number of applicants 135,000, which in calculational terms makes more than two full youth age groups. The situation will change completely when the number of young applicants begins to approach the average size of an age group, which is about 65,000 people.

The desired enlargement of the recruitment base will be possible if women in secondary education acquire better knowledge in mathematics and sciences and increasingly apply to these fields in higher education. This is one of the objectives set in the National Joint Action to increase mathematical and scientific knowledge. Although in 1997 60 per cent of all higher education graduates were women, their relative share in technical fields was only 16 per cent. According to international comparisons, Finland is unique in this respect. In 1975 for example the corresponding figures were 51 and 5 per cent, which now appears almost unbelievable. As point of comparison, women represented 46 per cent of graduates in sciences in 1997 and 38 per cent in 1975.

Efficient high-standard researcher training is an important requisite for the development of the information industry. In 1998 less than three per cent of those employed in R&D tasks relating to the production of electric and electronic equipment had postgraduate degrees, whereas the corresponding figure in all business sector research posts was nearly 4 1/2 per cent. The Finnish graduate schools began their second four-year term in 1999. There are some 100 graduate schools with nearly 4,000 doctoral students, of whom about 1,500 are in full-time postgraduate research posts established by the Ministry of Education and the Academy of Finland. About one fifth of the places are in ICT fields. Sixty of them have been established by separate funding as part of the action programme for additional training. There are 45 graduate schools and over 600 places in the science and technology fields; both are about 46 per cent of the total. These fields represented over 50 per cent of university research in 1997.

In 1999 three of the 17 centres of excellence in research nominated by the Academy of Finland operated in fields relevant to the information industry. In the 2000–2005 period the number of centres of excellence is 26, three of these (one new) are in information industry fields, employing some 200 persons in all.

Promoting the development of the information industries and their positive economic and employment impact will require further development and expansion of education in this field. It is necessary to improve the implementation of gender equality in both education and employment. The development challenges not only relate to secondary vocational education and training, the Joint National Action in Mathematical and Scientific Knowledge, and the programme for additional training, which, in a suitable form, must be made a normal part of activities (including funding) of polytechnics, universities and graduate schools, but also to the action taken by the Academy of Finland and Tekes to further develop top-level know-how and its utilisation. Further measures must be based on good cooperation between the public and private sectors.

The greatest challenge is naturally to ensure the success of the Finnish information industries, including software and content production, in global competition. The key question is investment in research which promotes this. Future growth in the business sector as a whole is, however, increasingly influenced by the extent to which intellectual resources and the domestic knowledge base enable activities to grow in Finland.

2.2

Promotion of social, economic and cultural development

Knowledge-intensive growth is business-driven in Finland. The public sector has supported this development efficiently by measures taken in cooperation with the private sector. The operational environments thus created are important for the success of enterprises' own measures and for all societal and cultural development. Conditions for knowledge-intensive growth, as well as for a knowledge-based society, are created within different policy sectors. Cooperation both between policy sectors and between the sectors and the national innovation system play an important role in this.

As has already been noted, business enterprises need supportive measures from the public sector in certain areas, such as access to a well-trained work force and know-how; the accumulation of intellectual capital; norms and standards; international rules of the game; competition conditions; and an atmosphere conducive to entrepreneurship. Corresponding input is needed to support social and cultural development under the responsibility of the public sector and to promote sustainable development. These areas of individual and societal life must be developed side by side with measures geared to strengthen the economy. This is a precondition for maintaining and developing the welfare society in the years to come. The public sector is an important utiliser of new knowledge and know-how and literally represents the customer's point of view in public procurement. For the public sector, tasks relating to the promotion of social and cultural development are just as demanding and challenging as tasks which concern economic development.

In its previous report, the Science and Technology Policy Council discussed in detail questions relating to science and technology policy cooperation with other policy sectors, focusing on general economic policy, finance policy, industrial policy, employment policy, regional policy, EU structural fund activities, social and health policy, environmental policy, the construction of the information society; and education policy. Overall, cooperation can be said to have developed positively. Different sectors regard the development of knowledge and know-how as an increasingly important element in their own activities. This was clearly stated in the programme of the new Government appointed in spring 1999. Regional development (the new programme for centres of expertise, the new EU structural funds

programme) and the cluster-based activities initiated in several sectors are examples of recent cooperation-based development measures geared to promote varied innovation within sectoral policies.

The Science and Technology Policy Council has been assigned a specific task by the Government to monitor and steer research which serves societal development, also known as "sectoral research", and the development of its utilisation in ministries and research institutes operating in administrative sectors. This work has been governed by the general model of sectoral research proposed by the Council in 1993, according to which ministries and research institutes operate in open research networks together with other producers and utilisers of research findings and organisations which finance research. The rationale is the need to continually improve the quality, relevance and impact of research, which is recognised as a strategic resource for ministries. Finland has clearly progressed in this area during the nineties. The Council has issued progress reports and recommendations concerning follow-up, the most recent dating from early 1999. Perhaps the most prominent recommendation, issued in 1995, concerned the evaluation of government research institutes. All the institutes had been evaluated by the end of 1999. The most important area of public research still outside systematic evaluation is the uncommitted research funds at the disposal of ministries.

Cluster-based activities constitute a new form of support for social and economic development instituted in the mid 1990s. Ministries, research and financing organisations, and business enterprises together have succeeded in creating significant research entities in support of technological and industrial development. Funds for launching the cluster programmes came from the programme for increases in government research funding adopted in 1996. Selected sectoral ministries were assigned resources for jointly planning and implementing the programmes. On the basis of preparations, eight programmes were included in cluster financing in the following fields: forestry, foods, welfare, transportation, telecommunications, national workplace development, and the environment. Most of the projects implemented within the programmes will end at the end of 2000, but there are already several plans for continuing action of proven worth. Apart from actual industrial clusters, it is possible to start research programmes in other fields. Good examples of areas discussed in this context are the environment and health, environmental technologies, safety and risk management, and the benefits inherent in Finland's northern situation.

Regional development is another important sector. It is vital to create regional innovation systems of the international standard alongside and complementary to the national innovation system. This is a question of improving the economic, social and cultural competitiveness of the regions based on their own resources, characteristics and needs. Successful measures promote employment, reduce differences between and within regions, and balance out internal migration in the country. The development of regional innovation systems is based on existing units into which the production and utilisation of knowledge and know-how concentrate in different parts of the country: universities, polytechnics, technology centres, centres of expertise, business enterprises etc. Cooperation between these operators and their efficient participation in national and international information and research networks boost development in the regions. Regionally based measures like this enable outlying areas to benefit from knowledge-intensive development.

Labour policy is an important factor for regional development. It is at the regional and local levels that the educational structure and the industrial structure in practice meet. The methods of educational anticipation and procurement must be advanced enough to make for good matching in terms of future regional development. This is in particular a question of interaction; for example, education alone does not create jobs in a given region. A trained work force is mobile and seeks work where education-related opportunities already exist. Good employability is one of the main objectives for the national innovation system. Failure in this will undermine the implementation of other objectives.

The programme for increases in government research funding over the years 1997–1999 was designed to intensify the functioning of the innovation system to the benefit of the economy, business and employment. The Ministry of Education and the Ministry of Trade and Industry invited an independent high-level expert group in December 1997 to evaluate the effects of this funding on society as a whole. The expert group will sit until the end of 2000, but at this point it has already noted that preliminary data on societal development indicate that the programme has had a positive effect on business and the economy. New, varied forms of cooperation have emerged between administrative sectors, Finnish and foreign research institutes, and financing organisations.

2.3

Identification of new growth areas and the promotion of business

The aim of the Government's industrial policy is to secure economic growth, improve employment and diversify the production structure. This entails that, alongside current efforts to promote industry and services, there is also input into new growth areas and the promotion of companies operating in them.

With the emergence of the so-called new economy, new growth areas in industry and services are increasingly based on knowledge and know-how. It is essential in terms of an efficiently functioning national innovation system to be able to identify new growth areas without delay and to assess their national relevance and scope and formulate the special development measures needed. In fact, one important component in science and technology policy is to actively identify new growth areas and respond to the challenges involved. In addition to branch-specific investigation, attention must also be paid to the corporate level, since successful business enterprises arise in all branches, both in traditional as well as in new and developing areas.

It is important for balanced and sustainable growth and risk management that input is made into several growth areas. Investment can be made in rapidly growing areas, on the one hand, and in fields expected to constitute growth areas in the future, on the other. Especially interesting are fields which are likely to grow rapidly, which have a significant effect on employment or whose development significantly supports other branches. Similarly interesting are areas where research findings can be easily utilised or which otherwise have societal relevance, for instance health care, the environment or security.

Measures are not restricted only by the capacity of the public or private sectors to invest in research, but also by access to trained R&D personnel. Personnel cannot necessarily be enlarged at the same pace as research needs, or the funding available for research. The best benefits are to be gained from high-standard research. This generally requires a solid research tradition and a high level of knowledge and know-how, which without exception are secured through the internationalisation of research. For top-level know-how to materialise and develop, systematic and long-term investment is needed in fields of strong research-orientation and in fields where new potential has been identified.

It is also important that research areas at the top international level in Finland have enough internationally competitive enterprises capable of applying and utilising the knowledge and know-how produced by the centres of excellence to benefit their own activities. In order for society to gain the largest possible benefit from research inputs, it is important that measures to promote the creation and development of growth-oriented business enterprises are taken on an equally long term as those relating to actual research.

Identification of future growth areas

One of the permanent tasks for science and technology policy is to identify future growth areas and their needs. Today's economy is characterised by a marked growth in services. This manifests itself as a relative growth in the services sector, on the one hand, and as the strengthening role of services in business activities within industry, on the other. At the same time the relative share of jobs in the services sector have kept growing and services have become increasingly knowledge-intensive. The information society development and the increased networking between business enterprises also promote this change. New technologies not only help to raise the productivity and efficiency of services and improve their quality, but also generate completely new innovative services. The clearest example of this trend is the increase in the services on offer on the Internet and through telephone networks, which is changing the traditional structure of the services market and necessitating completely new business models.

With the increase in knowledge-intensive services, R&D is growing rapidly in services, which is reflected in increased productivity and growing services exports. Business enterprises and the public sector are expected to continue outsourcing their auxiliary activities. As products and systems become increasingly complicated, different installation, maintenance and consultancy services become an integral part of products. Electronic commerce also increases. At the level of individuals, the development is influenced i.a. by service needs due to the ageing of the population and better availability of services targeted at citizens on the Internet and through telephone networks.

The marked growth in the electric and electronic industries means an increasing need for software competence in Finland. It has been estimated that often over half of the product development input in the electric and electronic companies is related to software development. It is a specific

challenge to the electric and electronic industries as a whole to capitalise on the opportunities inherent in software technology, but software know-how is utilised to a growing extent in nearly all social sectors. The turnover of actual software industry in Finland amounted to some EUR 1.7 billion in 1998, and the workforce in the field was estimated at 20,000. The share of firms producing software products was estimated to represent half of this.

Software products which require little customer-specific adjustment are a rapidly growing product group in the global enterprise and consumer market. Finland has good potential for a rapid increase in software industry. In 1998 the exports of Finnish software products grew by some 28 per cent from the previous year, and the current growth expectation in the field is much higher. Finnish strengths are high-standard and extensive technological know-how, internationally competitive domestic clientele and a very high-standard ICT infrastructure. Our general shortcomings are the small size of enterprises and limited experience of the development and marketing of international software products.

Apart from software production, a great deal of attention has been paid to the promotion of Finnish content production. This is based on the realisation that the prevalence of the Internet in Finland has not led to a corresponding growth in the supply of Finnish content and services. A project called Content Finland 2000–2004 has been planned to remedy this. The aim is to develop Finnish content and cultural industries into an internationally competitive branch alongside telecommunications technology. The means to this end are to promote the creation of new business enterprises and the activities of existing ones in the field. It is clear that success, especially international success, demands mastery of knowledge and know-how in many different fields.

Finland has been systematically investing in new biotechnology research, particularly in the utilisation of modern gene technology, since the early 1980s. Finnish biotechnology research is of the highest international standard in many fields and has also begun to yield promising commercial results. The number of biotechnology business enterprises is constantly growing. About twenty new enterprises are established every year; they are generally very research-oriented and mostly focus on the development of new precision drugs, diagnostics or equipment. New biotechnology has already generated some significant improvements, especially in the drug and enzyme industries, although the field has not yet fulfilled the global expectations for completely revolutionising the drug and food industries.

Promising prospects also exist in new materials. Materials and the production processes involved are developing rapidly. Owing to research in the field, there has been a significant growth in the selection of materials. This has created many new applications. However, business enterprises, especially small ones, have not been able to capitalise on the latest know-how and opportunities in materials technology. Central factors in the development of new materials are sufficient basic know-how, speedy and innovative application and due consideration to the environment. The high level of environmental protection can be turned into an asset in competition in all fields.

Promotion of business

The change in the industrial structure further highlights the significance of small and medium-sized enterprises, as knowledge-based business is gaining a more and more prominent role in job creation, especially in the services sector. The general trend is towards an increase in SME networks as part of the economic system as a whole. In fact, a decision has been taken to promote knowledge-based competitiveness through support given to intangible investments and the development of innovative business.

Diversified and efficiently operating financing markets are an important requisite for the creation of new enterprises and the growth, development and internationalisation of existing ones. In fact, the corporate stock market has developed favourably in Finland in recent years, and access to financing is no longer an obstacle to investment in most business enterprises. One typical feature of the Finnish stock-market is the small number of listing companies. Measures have been taken to develop special public funding to complement the activities of credit and insurance institutions, but this does not address the challenges relating to security market financing.

The active R&D of Finnish enterprises and their highly trained work force have attracted direct foreign investments especially to companies with good growth prospects. Overall, however, the relative share of these investments in corporate financing has remained fairly low in international terms. Owing to growing competition between banks, a great deal of loan capital has been made available to SMEs, and problems relating to collateral have generally decreased, according to surveys. The greatest problems are encountered by small high-tech production companies which lack collateral.

The important thing in promoting an ownership-based enterprise culture and attitudes favourable to it is the status given to entrepreneurship

in the education system. Entrepreneurship fails to attract especially the highly educated, because it is generally not very highly appreciated and the economic risks involved in setting up a business are high. Economic incentives are one important means of developing attitudes favourable to entrepreneurship. Besides access to financing, this requires increasing attention to eligibility to financing. An important element here is to improve financing and business know-how in companies.

The creation of new innovative business enterprises is typically hindered at the founding stage by difficulties in project evaluation, financial planning and market surveys. Funds are adequately available for the establishment and development of businesses after the necessary groundwork has been done.

Promoting the growth of innovative business enterprises thus requires that both the operational environment and the internal prerequisites of business enterprises are improved. An advanced equity investment culture is an essential element in the operational environment of innovative growth business enterprises. This means that equity investors also improve the growth potential of enterprises by providing necessary know-how for business development, as well as funding. It is the task of the public sector to support a long-term entrepreneur and investment culture and to put right operational shortcomings, among other means by securing opportunities for SMEs to finance their intangible investments.

In 1998 private equity investments amounted to 0.17 per cent of the GDP, which was the third highest rate in Europe. Only the United Kingdom and the Netherlands exceeded this. However, in 1998 only four per cent of capital in funds was estimated to have been invested in innovative start-up companies.

The favourable development of the equity market is slowed down by lack of efficiently functioning second tier markets. The Finnish enterprise culture does not traditionally support a large ownership base, nor are entrepreneurs usually willing or able to take risks entailed in strong growth. The fact that entrepreneurs do not have adequate knowledge about the requirements of and opportunities for different forms of financing further complicates the development of the equity market. Public equity investments are needed particularly to finance the start-up and early stages of business enterprises, since private equity investments are primarily made in companies in the growth or transition stages, where the expected profit is higher in relation to uncertainties and the work required by feasibility studies.

In a society where competitiveness is largely built on knowledge and know-how, flexibly and efficiently functioning national structures in the protection of intellectual property are a vital part of the innovation system. An evaluation commissioned by the Ministry of Trade and Industry in 1998 of the promotion and commercialisation of inventions identified several development needs, stressing in particular the need to strike a balance between the promotion of R&D, on the one hand, and invention and innovation on the other. Despite the favourable development, the promotion of invention and innovation is not yet satisfactory in terms of quantity or quality.

Finland cannot be competitive in all promising growth areas. The diversification of the production structure requires determined but selective investment in new growth areas. Since the growth sectors may vary greatly, the choice and input must be made according to sector-specific criteria. Each area has its own specific development needs regarding the creation and development of business enterprises. The features they share are that new business activities are heavily based on the utilisation of knowledge and know-how and that the business know-how of new enterprises needs to be strengthened. The shared features are reflected both in the creation of enterprises and their growth and development, which makes them a major challenge to educational development.

2.4

Dissemination and extensive utilisation of knowledge and know-how

As the growing input into research continues to produce more and more results, the knowledge and know-how which accrue must also be disseminated and utilised more efficiently in society. A particular challenge and opportunity is to integrate and utilise the advanced know-how in telecommunications and electronics industries in sectors and branches which are not growing so rapidly.

Needs and requisites of extensive utilisation

The dissemination and utilisation of knowledge and know-how are essentially influenced by access to and usability of knowledge – quality and cost factors – on the one hand, and by the recipient's ability and willingness to utilise

available knowledge. However, knowledge and know-how differ from traditional economic commodities in that they do not decrease in either quantity or value when used, rather the contrary is true.

While the amount of knowledge and know-how is growing very rapidly as a result of societal development, the capacities inherent in technological development lower the cost of the storage, dissemination and utilisation of knowledge and steps up and facilitates access to it. Instead of dissemination and access, the retrieval, management, assimilation and further processing of knowledge are emerging as central factors.

The Finnish industrial structure is more and more clearly based on knowledge and know-how intensive branches, and the competitiveness of business and industry is increasingly dependent on knowledge and know-how. Especially services based on knowledge and know-how are increasing rapidly. A knowledge-based economy has a strong export orientation, and a diversified industrial structure is not as susceptible to fluctuations as the traditional one. The change in the structure of the economy towards marked growth branches thus promotes the overall development of the national economy in the long run.

The rapid growth in the information and electronics industries is gradually having an impact on other sectors. The know-how accumulated there is spreading to other branches and promotes their development. In terms of economic growth and the sustainable development of society, it is important to support and step up this favourable trend.

Most new jobs have recently been created in high-tech branches, while low-tech jobs have been disappearing. Professional tasks which require high qualifications have been on the increase, and significant new recruitment has taken place within R&D in particular. On the whole, demand for know-how has grown, and the employment situation is best in high-tech fields. A similar development is in evidence in many other industrial countries, but the difference in the employment situation in the high and low tech branches is greater in Finland than in the OECD on average.

Finnish know-how relating to the information industries is undeniably at the international level, and it has a significant impact on business and industry and on society as a whole. The top ICT know-how and the growth in the information industry have direct and indirect effects on other industrial and service areas. There are three important channels through which ICT know-how spreads to other sectors:

- a) *Knowledge and know-how is transferred directly through cooperation and subcontractor networks in information industries* (contracted production, software industry, technical services, planning and training services, etc.).
- b) *The opportunities and know-how offered by ICT is utilised in other business activities to enhance development, renewal and competitiveness* (content industries and new media production, logistics, traditionally low-tech branches, knowledge-intensive services, etc.).
- c) *The know-how needs in the information industry are reflected in education and training, the availability of competent personnel and the mobility of personnel* (a marked growth in intakes in technological fields and the diffusion of competent personnel to other fields).

Apart from the production of telecommunications equipment, important fields utilising knowledge and know-how include the traditionally strong branches of Finnish industry: forestry and metal industries, mechanical engineering, the automotive industry, computer and office equipment production, medical electronics, consumer electronics and the automatisisation of process industries. New opportunities for utilisation also exist in other branches, as well as in rapidly growing knowledge-intensive services, such as the new media services.

The change is also reflected in the occupational structure in industry. Between 1980 and 1996 white-collar jobs have grown most rapidly in research, product development and planning, over 80 per cent on average, whereas the jobs which are disappearing most rapidly relate to routine administrative tasks.

The services sector has growing significance in the national economy, with knowledge-intensive and knowledge based services growing particularly rapidly. The global information society development is creating new kinds of markets for them, in which growth will be remarkably rapid. The new technologies make it possible to produce services of a higher standard than before, at the same time intensifying their production. The role and relative share of services in the end product also keeps growing; examples of these are installation, technical support, and advisory and maintenance services. The ageing of the population also creates need for more and new service.

The dissemination of new technologies and the extensive utilisation of know-how in other fields requires more widely based know-how both from business enterprises and from individuals. As the amount of knowledge keeps

rapidly growing, it highlights individual knowledge and skills: an ability and willingness to assimilate new knowledge will be an increasingly important asset. For business enterprises, this means constant input into organisational and staff development.

Growing national and international networking means that social and language skills will be a key factor alongside technological knowledge. Social and ethical aspects relating to the utilisation of knowledge will further highlight the importance of lifelong learning and the constant acquisition of new skills. The mobility of students, researchers and business personnel contributes to this development.

In Finland the mobility of intellectual capital is very high within sectors, but fairly low between sectors, which impedes the spread of knowledge and know-how across sectoral boundaries. This warrants increasing attention, and at the same time it is important to look into the possibility of setting up incentive systems in support of mobility.

The primary task of the education system is to take care of the development of citizens' capabilities, knowledge and skills in response to social change. The Government has recently adopted a new development plan which determines major policy lines for education and university research for the period 1999–2004. The plan stresses that contacts between working life and education will gain more importance with changing skill requirements. Citizens are expected to have more extensive professional education, as well as better qualifications. A valid response to the growing knowledge demands in the information society is to secure equal opportunities for all to study and upgrade their knowledge and skills, and to make extensive use of educational services. In view of growing knowledge and skill requirements and the rapid renewal of content, the ageing of the work force and the differences in the education of younger and older generations, it is important that education and training provision is based on the principles of lifelong learning.

Regionally comprehensive innovation network

Through a long-term effort, Finland has created a varied cooperation network of producers and utilisers of knowledge and know-how. A new element in the *educational network* which covers the whole country is a system of polytechnics, which have operated on a permanent basis since the late 1990s. Another network covering the whole country relates to the *R&D, researcher training and the development of technology*. Important partners here are centres

of excellence in education and research, graduate schools and joint research programmes. Besides universities, government research institutes and business enterprises are participating more and more actively in this network. The development of this cooperation has been supported from the outset by Tekes technology programmes.

The aim in networking is to put the best know-how at the disposal of all partners. The demand for top-standard activities undermines the regional coverage of the network when seen in terms of the physical location of its nodes – the education and research units of the highest international standard.

With a view to the development of regional innovation processes, there is also a need for networks which offer the best possible conditions for the utilisation of knowledge and know-how, i.e. ready access to research or high-tech know-how needed, regardless of physical location. A new challenge arises from a special object of regional development included in the government programme, namely to develop comprehensive innovation services through measures geared to strengthen the versatile knowledge and know-how network already existing in Finland. This is one of the projects included in the Government's "project portfolio"; the responsible organisation is the Ministry of Trade and Industry.

In practice, a regionally comprehensive innovation network means an expert network which supports and strengthens the creation and growth of new innovations and business based on them. In particular, it provides new entrepreneurs with access to all the know-how they need for commercialisation and for new knowledge-intensive business. The network provides management skills relating to the establishment and operation of business enterprises and to the protection of intellectual property and information about different forms of financing. The network also transfers and forwards necessary research findings and technology, and acts as a liaison between business enterprises and authorities when needed. Its operations are based on both private and/or public services.

The point of departure for the development of such an innovation network in Finland is good. The regionally operating employment and economic development centres and their technology units, the regional units of Finnvera and Finpro, technology centres and centres of expertise, regional environmental centres, authorities responsible for regional development, and universities and polytechnics all provide the framework for the development of innovation services. Resources for the development of the network come from the structural funds of the European Union, the

programmes for urban development and centres of expertise, and regional equity investment funds, as well as from national development projects. Another service which was raised in an international evaluation is the development of invention and innovation.

In the line of normal business operations, high-standard know-how in information industries is best disseminated within the branch and to the branches closest to it. The growth in business networking makes for efficient dissemination of know-how through direct contractual relations and cooperation projects. The network economy and the change in the working life due to knowledge-intensive growth make new demands on organisations to develop their ability to learn. One particular challenge for the innovation system is to disseminate ICT know-how, and the opportunities inherent in it, to other fields, and in particular to rapidly growing fields of knowledge-intensive services. The role of the public sector here is to promote the creation and operation of networks between enterprises as extensively as possible, to boost the mobility of intellectual capital in education, research and industry, and to help the regional innovation network develop its effectiveness and coverage.

2.5 Strengthening of the knowledge base

One of the foremost tasks for the public sector is to increase intellectual resources and strengthen the general knowledge base. Finland has a regionally comprehensive education system, in which the most recent addition is polytechnic education to be established on a permanent base in 2000, as well as a regionally comprehensive public research system, which has been strengthened by different measures in recent decades. From the international perspective, Finland is well-placed in terms of both resources and infrastructure. On the whole, the basic structures and operational environments for knowledge and know-how and their utilisation are in place.

The constantly growing significance of knowledge and know-how both for the individual and society as a whole has focused attention everywhere on efforts to strengthen the general knowledge base. The fact that the economy is increasingly based on knowledge has generated interest in an efficient and smoothly running innovation system. For a small country like Finland, which bases its development on knowledge and know-how, it is vital to secure conditions for long-term and sufficiently widely based development, otherwise it is ill-prepared to meet the future challenges.

The globalisation of the economy and growing open competition have moulded the principles which steer public sector measures in educational and research development. This is clearly seen in the way in which the external contacts of education and research have been developing as well as in the weight given to the expectations of different, including new, utilisers in policy formation. The Science and Technology Policy Council has already noted earlier that the stress placed on this benefit consideration is positive for education and research organisations. The aim is to strengthen education and research and to improve their quality – to increase knowledge and know-how through education and research. In this, care must be taken to base the development on a broader view of the challenges and tasks of education and research than the current interest prevailing at any one given time.

Strengthening the knowledge base is a continuous process. It must address both the base and tip of the "knowledge and know-how pyramid". All citizens must be provided with the basic knowledge and skills they need to operate in a knowledge-intensive society. This provides a basis for life management and intellectual and material development. Basic security in education based on the principle of equality is needed to prevent alienation and exclusion. It is equally necessary for Finland to invest in top-level know-how and its development in order to be able to progress in the forefront of knowledge and know-how and of the information society development in the future. Standing still means decline.

The knowledge base is thus facing a variety of development challenges. Alongside the traditional cultivating mission of education and research, one emerging question is matching the educational and industrial structures both nationally, regionally and locally. Good matching is also increasingly important in higher education. More and more stress is placed on the quality and content of education. A solid education includes many other elements besides specific vocational and professional qualifications, from proficiency in languages to cultural and social skills. At the same time, it is true that even a solid basic education or training is only a point of departure on which lifelong learning is based.

The response to the challenges arising within research and researcher training has been a determined effort to improve the quality and relevance of activities, to increase evaluation and foresight, and above all to strengthen and widen the resource basis, structures and internationalisation of activities and increase competition-based research financing. Graduate schools, the system of postdoctoral researcher posts, centres of excellence in research

and other development measures launched in recent years address several challenges at the same time. These include the growing needs and expectations of society, as well as development needs relating to the internal operation of the research system, creative research environments and real prospects for research careers.

The development measures already implemented have clearly contributed to the standard, effectiveness and visibility of Finnish research. Research can also offer more scope for applications. However, the public research system is still under various pressures for change, and a determined effort is needed to carry on the development.

Sections 2.1-2.4 pointed out important development objects to which the public sector must respond by continually improving the knowledge base. The public sector mission is not, however, confined to the creation of special competencies but is general by nature. For example, to yield a balanced outcome the joint national action to *strengthen mathematical and scientific knowledge*, which is in fact included in the government programme, needs to be supplemented by input into the humanities, social sciences and business know-how. This concerns individual, economic and other societal activities.

The need to enhance mathematical and scientific knowledge is an example of a challenge which has demanded and will demand measures throughout the education and research systems. It also requires cooperation with the private sector, although it is a matter primarily for the public sector. The objectives of the joint national action 1996-2002 were recently revised. Although these objectives are by no means excessive in relation to the stated needs, they are still very demanding. The qualitative and quantitative development objectives concern the whole range of these disciplines: the training of class and specialised subject teachers – a special concern being class teachers' impending wide-scale retirement; the improvement of teaching and learning outcome; finding ways to stimulate pupils' interest in the comprehensive school and especially the upper secondary school; and ensuring the contentual development and expansion of undergraduate and postgraduate education based on full use of the recruitment base. This is a question of both strengthening basic mathematical and scientific education and satisfying the growing demand for professionals in these fields. The capabilities of other professionals to utilise mathematical and ICT knowledge in the development of their own work also need to be improved. The mathematical and scientific fields exemplify the need to strengthen the base and top of knowledge and know-how at the same time.

The overall starting point for *strengthening the knowledge base* is the opportunities inherent in education and research and the foreseeable needs relating to the use of these opportunities. Information about future developments and methods for its acquisition have a more and more prominent place in the formulation of development measures. *Technology foresight* and *science watch*, together with the evaluation of the present situation and present level are widely used tools in science, technology and innovation policies. In Finland the foremost organisations for research evaluation and foresight are the Academy of Finland and the National Technology Agency Tekes. The Higher Education Evaluation Council has an important expert role in the evaluation of higher education and its organisation. National and regional anticipation is equally important in education.

Another important general development area is to *increase international cooperation* in the planning and implementation of measures both at the EU level and with other areas. In view of the globalisation of the economy, it is increasingly important to have access to up-to-date information and to generate new knowledge of the highest international standard. Alongside the network economy, there are international networks for the production of knowledge and know-how and its financing. Spearhead programmes and projects are more and more frequently internationally financed, not only by international organisations but also jointly by national financing and expert organisations from different countries. One of the challenges facing Finnish science watch is the participation of Finnish financing and research organisations in networks relevant to Finland.

One important element which has emerged in the 1990s alongside the national-level efforts is *regionally-oriented development in different parts of the country*. Regional development is increasingly based on knowledge and know-how and their efficient utilisation. Mutually supportive national and regional measures designed to achieve the international standard can help to gain significant synergy benefits. One important means of strengthening the regional knowledge bases is close cooperation between regional producers of knowledge and know-how and their interaction with utilisers. Alongside other partners, *polytechnics* have an ever clearer role at the regional level within the development of education and working life and especially in expertise which serves SMEs in various ways.

The question of ensuring *appropriate resources for developing the general knowledge base* is both controversial and challenging. Finland makes a significant *investment in education* in international terms. Measured as a

GDP share, the educational investments made by Finland are among the OECD top at all educational levels. The general education system is financed almost entirely from public funds in Finland. The per-student financing volume in Finland is clearly above the OECD mean, with the exception of higher education, in which it fell ten per cent short of the OECD mean based on purchasing power parity in 1995.

As regards *research investments*, it can be correspondingly noted that public research funding in Finland is among the highest in the OECD or at least is a good average in most respects. However, the share of basic university research funding in relation to the overall government research expenditure and the share of public financing in corporate R&D are small in international terms. Nevertheless, both of them represent the average OECD level when measured as a share of the GDP.

The evaluation of both educational and research investments must naturally take account of the industrial structure in the country, student and teacher numbers and other considerations which influence comparison. When the point of departure is to develop Finland as a knowledge-based society, it can be said with justification that *universities should receive more public core funding for the production of knowledge and know-how* than is now the case. In Finland, university core funding is based on a Higher Education Development Act. According to the government programme, this will be the case even after the provision concerning university resources ceases to be in force in 2001. According to a committee appointed by the Ministry of Education to look into the matter, the provision should be kept in force until 2006, with due consideration to the general rise in costs. Another factor to be taken into account is the change in the extent of university activities as measured by the number of degrees awarded. This would secure the real level of university operational expenditure and take account of changes in activities. In this way the link between the objectives and resources would be realised.

3

General conclusions

The development needs and tasks discussed in section 2 constitute a major challenge to the national innovation system as a whole. This section examines in more detail what development measures are needed in different parts of the innovation system. For practical reasons, this discussion falls into two parts according to the main mission of the operators involved: the development of knowledge and know-how and the utilisation of knowledge and know-how. Some organisations are involved in both, which reflects the fact that the production, development and utilisation of knowledge and know-how fundamentally form part of various learning and innovation processes, which in the final analysis make up the innovation system. Questions relating to financing are discussed in section 3.3.

3.1

Development of knowledge and know-how

This section deals with the development of education and training, and basic and sectoral research and technology, with a special focus on the organisations responsible for development and needs relating to their

activities. The end of the section summarises the development of intellectual resources required by R&D.

Education and training

The overall development of education and training is governed by a Development Plan for Education and University Research, which the Government confirms every four years. The plan is prepared by the Ministry of Education and is sent out for an extensive opinion round before it is adopted. The Development Plan for the period 1999–2004 was recently confirmed. According to this plan, Finland's success will depend on high-standard education and research, innovative know-how and the utilisation of modern ICT. Special attention must be paid to ICT in studies and teaching.

From the point of view of the Science and Technology Policy Council, there are *five areas of great relevance* in development. They are the keys to the development of knowledge and know-how. The measures also concern the development of educational structures.

- A general rise in the level of education through both qualitative and quantitative development,
- Special measures for enhancing mathematical and scientific knowledge,
- Special measures in other fields,
- Matching of education and labour market demands, and
- Lifelong learning.

International cooperation is integrated into all development measures and must be further strengthened. Internationalisation must be promoted with emphasis on two-way cooperation and on education for internationalisation.

The need to *raise the overall level of education* springs from the demands of life management in an increasingly complicated world and in an increasingly international society. The principle of equal opportunity in education requires, for instance, that all citizens have the basic skills and knowledge they need to operate in an information society. These include cultural, social and communication skills, as well as cognitive skills. The demands of vocational and professional know-how and knowledge are equally exacting: secondary education is considered the minimum requirement for

lifelong learning and success in working life. This clearly calls for the development of vocational education and training.

Finns are still motivated to educate and train themselves, and there are no clear indications that salary levels would have undermined this motivation at least among the younger age groups. But as the qualification requirements keep growing and evolving into lifelong learning, a way must be found to support vocational and professional upgrading, for instance by the establishment of incentive systems.

There are increasing pressures stemming from the direction of higher education for the development of secondary education and training. Polytechnics and universities are faced with a growing demand for a highly educated work force. Their capacity for enlarging intakes increasingly depends on the recruitment base, on the qualifications provided by secondary education for further education.

The basic mission of a polytechnic is to satisfy the national and regional need for professionals. The universities' mission highlights higher education based on research, the promotion of scientific knowledge, and a responsibility for seeing that Finnish research, education and teaching achieve a high international standard in keeping with ethical principles and good scientific practice. The question of postgraduate polytechnic degrees is currently under discussion.

During the 1990s a great deal of attention was paid to postgraduate education. The graduate schools launched in 1995 have proved an efficient way to lower the age of new PhDs and to produce high-standard experts both for R&D and for other areas. The annual number of doctorates has been growing rapidly, and was over 1,000 in 1999. PhD candidates are clearly younger than before. The challenge is to carry on and further develop these trends with a view to maintaining the high standard and recruiting a sufficient number of competent postgraduate students in all educational fields to satisfy the manpower needs in qualitative as well as quantitative terms.

Special concern has been aired in Finland regarding the quality and quantity of *mathematical and scientific knowledge*. This concern is fully justified. *All* measures which enhance knowledge in these fields, from basic education to top-level know-how, are welcome. Success in development requires promoting women's participation in particular. As already mentioned, subject teachers will soon begin to retire in great numbers. This has been known for a long time, but no development measures taken so far have yielded the desired results. One objective in the joint national

action to increase mathematical and scientific knowledge is that 140 subject teachers majoring in mathematics, 90 in physics or chemistry and 80 in biology or geography will graduate in 2002. These are minimum targets, which in view of the present situation are very demanding. The situation is unfortunately similar in the teaching profession overall. The estimated need for new teachers in general and vocational education is as high as 15,000 over the next five years.

The programme for increasing education and training in fields relating to the *information industry* has proved important in partly satisfying the rapidly growing manpower demand. This is also a question of the mathematicalisation of society, in other words, that people need certain mathematical and scientific grounding as part of their general education in order to understand and deal with matters they encounter in their day-to-day activities. The programme should be continued, although not in the form of a separately planned and financed programme, but as part of normal expansion of activities from a level formerly seen as adequate. What is involved here is not random fluctuation, but actual prioritisation of fields relating to information industries in education and training. This reflects the rapid change taking place in the industrial structure.

The education system must be able to implement corresponding development measures in other growing areas. Potential new areas are also suggested in this review. The areas may vary greatly, from extensive development of business know-how to research into social and cultural change and development potential. Practical measures are taken by different responsible organisations, depending on which parts of the education and research system are involved. A timely response to challenges requires *wide-scale development of educational anticipation and provision* at all levels of education, be it that initial education and training is more and more clearly the starting point for lifelong learning. Success is equally important in the anticipation of educational content as it is in quantitative anticipation.

The matching of education and working life is primarily tested locally and regionally. Meeting future needs and capitalising on future opportunities requires the best possible matching of the industrial and educational structures in regions. In supplementing institutional vocational education, apprenticeship training, when successfully implemented, fulfils the requirement of good matching, and should therefore be increased substantially.

With the growing significance of *lifelong learning*, it is increasingly important to secure a solid basis for learning and learning opportunities, as

well as practical skills and knowledge. This requires joint action by the public and private sectors, for instance, in the assessment and recognition of knowledge and know-how and in credit transfer. The financing of education should also be adjusted to promote lifelong learning better.

Basic research

The creation of new knowledge through research provides the foundation for the national strategy based on knowledge and know-how. Publicly funded basic research is a critical resource in an innovative society. According to the government programme:

- Universities will be developed to enable them to take care of high-standard basic education, researcher training and scientific research,
- The public funding of the Finnish innovation system will be developed to support high-standard innovative research, regardless of the field of science or art,
- The policy of centres of excellence will be continued.

One of the important tasks of universities is to promote high-standard independent research. It has been noted in this review and elsewhere that the benefit consideration is a strong element in the relations of business and the rest of society with universities. The growing external interest in universities is a positive development, provided that universities are able to capitalise on the new activities and resources it brings in their basic mission. Faced with a growing range of tasks and growing external resources, universities must find solutions in their management and action strategies to the problem of how to develop the institution as a functional whole in which the different parts strengthen each another. Success in responding to these challenges is as critical for universities as the future development of their core funding. In its Development Plan for Education and University Research 1999–2004, the Government calls upon the universities to devise an overall strategy which also provides for the allocation of external funding.

The basic prerequisites of **university** research have been assessed by a committee appointed by the Ministry of Education in 1998. According to its report, *the assets of Finnish university research are a strengthening research-oriented development trend; good overall development of research resources* (core and external funding combined); *input into important areas* (the graduate school system; the information strategy for education and research; the

development plan for biotechnology and molecular biology); *a rising scientific standard; increased flexibility and efficiency; growing cooperation with business and industry; the development in physical research environments* (premises, information network services, scientific computation); and *increased decision powers*.

According to the report, *needs relate to strategic development; a balanced financing structure* (own funding in relation to external funding); *infrastructure* (instrumentation, collections); *degrees, teaching and postgraduate education* (long study times, the high average age of new PhDs); *diversification of the financial basis and financing mechanisms* (e.g. pricing of research and educational services); and *basic conditions for projects financed by the Academy of Finland* (in the form of an overhead extra).

The committee's observations are still valid and topical. The basic conditions for university research must be further developed, though many fundamental things are in order. The measures needed are much more diverse than just the core funding of universities, which has been given most attention in public discussion, although this too is important. The committee report provides a solid basis for an analytical scrutiny of development measures.

The Academy of Finland and the National Technology Agency Tekes are the most important external sources of financing in university research. Their competitive, selective research resources have been systematically increased in recent years. The financing decisions made by the Academy in 1998 allocated over EUR 110 million to universities, amounting to 80 per cent of the Academy's whole financing volume. Corresponding decisions made by Tekes included nearly EUR 80 million of research funding allocated to universities. In addition, some EUR 25 million of the funds allocated by Tekes to companies was channelled to research institutes and higher education institutions through different corporate projects. It is worth noting that the Academy and Tekes have stepped up their cooperation in the 1990s, especially in the planning and implementation of research programmes. The combined financing volume of these two organisations exceeds EUR 135 million.

Freely competing research projects are the major recipients of Academy financing. This support to "high-standard innovative research regardless of the discipline" represented nearly 40 per cent of the Academy's overall financing volume in 1998. Research programmes, which are often jointly implemented by the Academy and other organisations, received almost EUR 25 million, or 18 per cent of the Academy's whole financing volume. The aggregate sum allocated to research networks, researcher training and

international cooperation was the same as that given to research projects. The funding allocated to centres of excellence, which are given a great deal of attention in public discussion, is only 5 per cent of the whole volume, or EUR 7.5 million.

The main direction of development in the Academy's activities is to further strengthen the knowledge base in the long run and to ensure preparedness to respond to the global transition in the economy, culture and science. The priority is to promote professional researcher careers and creative research environments. The centres of excellence and research programmes in strategic fields represent an important, as yet partially untapped, resource for achieving the stated objectives.

One objective defined in the Development Plan for Education and University Research is that by 2002 *universities will allocate at least three per cent of their 1999 level core funding to measures geared to promoting teaching and research and strengthening priority fields.* The Science and Technology Policy Council notes that this is also a viable way to allocate additional resources to university core funding. One way to encourage structural renewal in universities is to grant a corresponding sum to the same targets to which universities allocate their own operational funds which have been freed from other uses.

Another reform relating to the university financing structure, and which is still waiting to be implemented, is the inclusion of an *overhead extra in external financing*. Universities must carefully weigh all external funding to make sure that the financing covers all the costs of the activity. Practice is still heterogeneous in this respect, nor is cost calculation at a level which would ensure that all the costs are known. The strictest demand for cost coverage concerns contracted teaching and research, but it applies to all other external financing. The matter has been discussed publicly in connection with Academy financing, but concerns other organisations as well. In the Academy's case, this is a question of adding 15 per cent to financing decisions, as far as they concern salaries. The Science and Technology Policy Council notes that the matter must be addressed according to plans, i.e. the necessary funds should be added to the Academy's commitments, as proposed in section 3.3.

In an international comparison based on purchasing power parity, the calculated price of one person-year in Finnish university research is still fairly low, 20 per cent under the EU average and nearly 30 per cent lower than the Nordic average. Among other reasons, this is due to difficulties encountered in calculating the price of activities financed externally and the

relatively low university core funding, which is also indicated by international comparisons.

Sectoral research

Social, economic and cultural development is increasingly based on new knowledge and know-how. In this, ministries and other public agencies are in a key position. They finance, commission and contract research and other expert services needed in the development of their policy sectors, and they have responsibility for the efficient and competent utilisation of the knowledge thus acquired. Research institutes in their administrative sectors are traditionally the most important producers of knowledge and know-how, and much attention has been paid to their development in the last ten years.

The Science and Technology Policy Council has contributed to the overall development of sectoral research, as discussed in section 2.2. The activity is twofold in that efforts are made to develop sectoral research and its organisations simultaneously as part of the public research system and the central administration. The latter has above all been advocated by ministerial working groups looking into administrative development and by the Ministry of Finance. In this regard, future development is based on a decision taken in September 1999 to carry on the reform of public management. For the Council the development of sectoral research is a permanent task.

Ministries have a key role in this development in several respects. The extent to which and how speedily new knowledge is applied to societal development largely depends on the ministries' ability to utilise sectoral research. This is why it is especially important that each ministry's leadership is committed to implementing a knowledge-based management culture throughout the ministerial organisation. This also enables the ministries to steer sectoral institutes by target outcome better and to act, where applicable, as a knowledgeable and demanding customer in the development of the administration and the public service systems.

It is also up to the ministries to create cooperation networks according to the general model of sectoral research and to develop horizontal cooperation across administrative borders. In this respect, progress has been made in recent years, the role of *clusters* being especially important. Cluster-based activities is also another example of an action model which incorporates cooperation and competition in a balanced way: competition-based research

funding is used in cooperation to implement joint research programmes. It is encouraging that this form of cooperation has proved so successful that many administrative sectors are planning to continue cluster-based activities in new programmes.

In its statements, the Science and Technology Policy Council has recommended an increase in ministries' uncommitted research funds. This recommendation has chiefly been implemented in the domain of cluster financing. As was noted in section 2.2, the uncommitted research funding at the disposal of ministries is the most important area of public research activities outside of systematic evaluation. This financing, which amounts to about EUR 170 million, consists of three distinct entities: (1) *government compensation to health care units for research carried out under the Specialist Health Care Act* ("EVO" financing by the Ministry of Social Affairs and Health, EUR 60 million in 1999); (2) *the cluster financing* discussed above, which is included in the programme for increases in government research funding 1997–1999 (EUR 10 million), and (3) *other research funding at the disposal of ministries* (about EUR 105 million), including membership fees and other contributions paid abroad. The Council has recommended an independent evaluation of the EVO financing, and cluster financing will be evaluated as part of the additional financing programme. Systematic measures should be taken to evaluate other uncommitted funding in the administrative sectors. The first evaluation projects are already being planned, which is an indication of the administration's interest in the evaluation of their financing and its effectiveness.

The ministries should commission external organisations, or have them commission, independent evaluations of their uncommitted research funds – what is required, after all, is more than mere self-evaluation. In Finnish conditions, these external organisations would be primarily the expert organisations in government research funding: Tekes and the Academy of Finland. They could be assigned the task of jointly obtaining evaluators for the purpose from Finland and abroad. At this point it would be useful to find out whether the use of uncommitted research funds should be evaluated separately in every administrative sector or whether it is possible to combine several projects to achieve synergy. Another matter to be considered is the eventual need and opportunities for creating the same kind of project database in sectoral research as is currently under construction in the cluster programmes.

Ministries also have a key role when structural solutions are sought for the development of sectoral research. This has already been done to some

extent in the internal development or reorientation of individual research institutes, but no reforms have been implemented across institutional boundaries even within administrative sectors, despite concrete propositions to this end. The Ministry of Education has a special task in further clarifying the role of universities and polytechnics in sectoral research and steering them by target outcome towards closer sectoral cooperation. Both of these issues will be taken up in the public management reform, as has the question of developing the status and mission of development centres.

A new knowledge base has been created through systematic evaluation for the operational and partly structural development of **research institutes**. The vertical relations between ministries and research institutes, such as steering by target outcome, have clearly advanced, perhaps even at the cost of horizontal cooperation. The development work done by the institutes themselves has gained momentum from evaluations. This has happened at a time when the research core funding has been declining. The financing structure and financing volume of research carried out in government research institutes has evolved as follows (comparison with the corresponding changes in universities):

A) Share of own financing in research expenditure 1989–1998, %

	1989	1993	1998
Research institutes	66	66	50
Universities	66	59	53

B) Research activities 1993–1998, EUR million and %

	1993	1998	Change
<i>Research institutes:</i>			
- own financing	215	186	- 13
- external financing	110	188	+ 70
Total	326	374	+ 15
<i>Universities:</i>			
- own financing	217	313	+ 44
- external financing	150	273	+ 81
Total	367	586	+ 59

Source: Statistics Finland

Research institutes' own funding has decreased, also nominally, during the period under review, but they have been able to increase external funding to the extent that the overall volume of the institutes has not declined. These trends have together led to a steep decline in the relative share of the institutes' own financing in the mid 1990s. At the same time, the overall volume of university research has been growing rapidly, being over 55 per cent higher in 1998 than that of research institutes. The difference has grown further since.

The numerical data show that research institutes are facing varied, often heavy, pressures for change. In this situation, it is increasingly important to be able to develop the research institutes, as well as the whole sectoral research field, functionally, based on operational needs. The Science and Technology Policy Council has divided the research institutes into three categories according to their loosely interpreted research object: research institutes studying (1) nature or natural resources, (2) people as individuals and in their operational environments, and (3) culture and society. Development needs have been identified both across and within the three institute groups. The Council's recommendations concerning these are given in section 4.

As regards development needs, it is worthwhile in this context to make the general observation based on the evaluations of research institutes that the quality of activities was generally rated good, and better than their relevance. Thus special attention must be accorded to improving the relevance of activities, although the research institutes often have purely scientific significance as well. They may have developed important research fields in a way which would not have been possible in the academic environment which is divided into educational programmes and disciplines.

The Science and Technology Policy Council has identified specific functional development needs mainly in groups (1) and (3). They relate to the development of research and educational cooperation with universities, on the one hand, and a special study on the development, and eventual reorganisation, of sectoral research in social science and relevant sectoral research institutes, on the other. The study must be conducted in close contact with the process of central administration reform.

Technology

The bulk of development challenges discussed in section 2, especially as concerns the public sector, relate to the domain responsible for strengthening technological knowledge and know-how in Finland. On the other hand, it

is increasingly understood that in order to enrich society and the individual's life and to open up opportunities to this end, technological development must be accompanied by a social, ecological and cultural dimension. Techno-economic considerations are not by themselves sufficient.

The range of operators in the development of technological knowledge and know-how is wide in Finland. The foremost organisations include the universities, which belong to the administrative field of the Ministry of Education, especially the Universities of Technology and faculties of technology, the Academy of Finland, and polytechnics, whose mission is being developed towards the SME sector in particular. Research institutes often play an important role in developing technology in their own sectors. The following examines two important organisations with a specific responsibility for technology development in the administrative field of the Ministry of Trade and Industry.

In recent years the **National Technology Agency Tekes** has been the most rapidly growing organisation in the Finnish public research system. Its resources have grown from EUR 170 million in 1993 to 420 million in 1999. This is the result of a determined effort. It has been generally seen that technology provides a means for improving the competitiveness of industry and services, renewing and diversifying production structures, and thereby creating a basis for employment and welfare.

This rapid growth has been primarily achieved by two means. The Ministry of Trade and Industry has revised its own resource allocation to include significant resource transfers to Tekes, which has also been a major recipient of resources allocated within the additional research funding programme (1997–1999). The overall aim of the programme was specifically to benefit the economy, business and employment. These funding measures, together with other nationally and regionally implemented development measures (15 employment and economic development centres and the domestic Tekes units in these centres), have helped to create a research and technology network which covers the whole country.

The rapid development of Tekes and its strong status in the Finnish research and innovation system have meant that it has been assigned new challenges in public discussion. The Science and Technology Policy Council has estimated that the positive development in public research funding has also accelerated the growth of private sector R&D investments and helped them to stay in Finland. Nor has the marked growth lowered the standard of the research projects thus financed; on the contrary, the enhanced

knowledge base appears to have improved the productivity of research investments.

It is to be expected that the growing Tekes financing in the knowledge-intensive services sector and in cluster projects will yield good results. The digital revolution and the subsequent information society development will open up new opportunities for both economic growth and employment. One important challenge facing Tekes is a need to intensify measures relating to the commercialisation of technology and to globalisation, which is more evident in technology than in other research. In terms of education policy planning, it is important to make efficient use of company feedback to Tekes, concerning growth prospects in different technology fields and branches and their needs.

To summarise, the priorities in the technology sector relate to a need to widen the basis of knowledge-intensive growth, to secure conditions conducive to the growth of business sector R&D in Finland and to promote the commercialisation of research. International cooperation must continue to be strengthened in all sub-sectors, especially in the leading centres of technological development. Expertise on the commercialisation of technology and technology transfer mechanisms is in short supply, and determined educational measures must be taken to enhance it. Several development projects have been initiated in the protection of intellectual property and employee inventions, but there are still various needs, starting from a legislative reform.

In addition to the inputs mentioned above, priority must be given to the *development of regional-level measures*. Sustainable promotion of innovation in regions demands increasing attention. The Science and Technology Policy Council has proposed that a comprehensive network of innovation services be established alongside the traditional education network and the R&D network mentioned above. The government programme highlights the development of the science parks, centres of expertise and Tekes, which will support development in the whole country. The challenge is to be able to reconcile the international, national and regional points of view in a mutually supporting entity.

The fact that technological development and the utilisation of technology are increasingly closely linked to overall societal development and its promotion also makes increasing competence demands on Tekes, firstly towards commercial expertise, but increasingly also towards other societal, scientific and humanistic knowledge and know-how. The resources available

to Tekes, as well to the Academy of Finland, for preparative work have been increased as part of the additional research financing programme. Access to varied expertise by these organisations is becoming increasingly important. The growing cooperation between Tekes and the Academy will enhance the expertise at their disposal.

The **Technical Research Centre of Finland VTT** is a central expert organisation in technological and techno-economic R&D. Its role in the production, application and transfer of knowledge and know-how has been constantly growing. It is also in a key position as a developer of international technological cooperation and as a participant in EU research programmes. Its significance in EU cooperation is clearly manifested by the fact that its participation in the Fourth Framework Programme equals the combined input of the four next largest participants. Alongside this positive trend, measures must be taken to intensify cooperation with the USA and Japan, towards which Tekes and VTT, among others, have already taken steps.

Development of intellectual resources

In 1998 R&D employed over 60,000 persons in Finland. Between 1993 and 1998 the growth rate was nearly 19,000, or 3,750 persons a year. Since 1995 the annual growth has accelerated, and was over 4,300 persons between 1995 and 1998. Moneywise, research grew by EUR 370 million on average from 1995 to 1997, and after that by 420 million a year, according to a Statistics Finland estimate. The rapid growth in research personnel is thus continuing.

The decisive factor for quality and effectiveness of R&D is the education of research personnel. In the 1990s rapid research growth has been characterised by *a rise in the average level of education* among the work force. In 1987 the relative share of university graduates of all research person-years was 40 per cent, whereas by 1998 it had already exceeded 50 per cent. Besides general measures taken to promote research careers, this positive trend is due to a sharp increase in the number and proportion *of women in research*. The quality of the R&D has remained high and can be further developed. Raising the annual number of doctorates from the present 1,000 to 1,400 is justified.

The growing demand for research personnel follows the growth in research funding. Since 1993 the number of R&D personnel in the business sector has increased by over 2,500 persons annually in net terms. The growth has gathered speed in the past few years, now exceeding 3,000 persons a

year. The private sector research personnel represented over 50 per cent of the whole research personnel in Finland in 1995. The relative growth has continued since then.

In universities and government research institutes the net increase in research personnel has been about 1,600 annually. The growth has been more rapid in universities than in the rest of the public sector, about 1,100 persons a year over the period 1995–1998. Most of these have been hired by means of external funding. Nearly 65 per cent of university research person-years were externally funded in 1998, whereas in 1993 the figure was 55 per cent.

The marked growth in business sector R&D has been selective in terms of educational fields. Nearly two thirds of growth in research volume between 1995 and 1998 concerned fields relating to electrotechnical industries. The need for research personnel in the public sector concerns all fields of research and education, and is much more evenly distributed among them. One manifestation of this is that the distribution of disciplines in university research has changed fairly little over the 1990s. For instance the change in research in the humanities and social sciences was two percentage units (from 32% to 30%) between 1991 and 1998, which in terms of funding means a nominal *growth* of 45 per cent in research. Person-years grew by over 70 per cent in the humanities and social sciences, which is five percentage units more than the university average. This otherwise positive development was accompanied by a fall in the calculational price of research person-years both in absolute terms and in relation to the price of person-year in other university disciplines.

Overall, the development of intellectual resources in Finland has been positive. It is connected with a general aspiration to raise the level of education, which is clearly seen in the rapid development of the polytechnic system during the nineties. This has raised the number of new students in higher education to nearly 70 per cent of the average age group. The rising level of education has meant better employment.

As a result of the challenges discussed in section 2, varied development measures need to be taken to increase intellectual resources further. As regards higher education in general, it is no longer possible to widen the recruitment base to any great extent. From the R&D viewpoint, a determined input must be made to improve quality both in higher education and secondary education, and alongside this, to develop adult education according to the principles of lifelong learning.

Another important task in the development of both research and intellectual resources is to promote *international cooperation and researcher mobility*, with special emphasis on two-way action. There is still a great deal to do in both respects. According to a study made by the Science and Technology Policy Council together with the Ministry of Education, the internationalisation of researchers has only progressed to any great extent in the nineties. The new graduate schools and the researcher PhD system have contributed greatly to this development, as has action taken by the EU to promote researcher mobility. Young researchers have an especially good motivation for international cooperation, which bodes well for further development of research.

3.2

Utilisation of knowledge and know-how

The following especially focuses on development objects and needs in the utilisation of knowledge and know-how from the perspective of the organisations concerned, which, on the one hand, are the support and service organisations in the public sector responsible for promoting the dissemination and utilisation of knowledge and know-how at both national and regional levels. On the other, it concerns the ability of the private sector and individuals to make use of knowledge and know-how. The promotion of the utilisation of, and especially access to, knowledge needed in education and research are governed by "Education and Research in the Information Society, a National Strategy for 2000–2004". It provides for the development of information content, as well as services supporting education and research and their development. The strategy also seeks answer to the challenge of multidisciplinary knowledge in the information society, which has not been sufficiently studied.

The tasks ahead are very demanding because they involve both the need to make knowledge and know-how produced abroad available in Finland and to disseminate domestic knowledge and know-how to users. Less than one per cent of the world R&D is conducted in Finland, which means that development here largely rests on knowledge and know-how produced elsewhere. A special challenge this poses to both the public and the private sectors is to identify and disseminate relevant knowledge and know-how.

Utilisation at the national level

Finland has made a substantial and long-term investment in the production of knowledge and know-how. The efficient utilisation of the know-how thus accruing requires clear and close cooperation between many different partners. This means coordination of the aims and activities of public support organisations both between sectors and between the national and regional levels, as well as the best possible matching between the capacity of the public sector and the needs of the private sector. The national cluster programmes are an excellent example of this kind of multidimensional cooperation. The following examines different means at the disposal of the organisations involved to promote the utilisation of knowledge and know-how.

The **National Technology Agency Tekes** plays a central role in implementing technology policy. It participates actively in international technological cooperation. As the clearly largest organisation financing R&D, Tekes has a great responsibility for promoting the utilisation of research findings.

Technology programmes are an important tool by which Tekes steers research into important fields in the longer term. They are extensive joint efforts between companies, research institutes and institutions of higher education. They always provide for utilisation as well, because the users are involved in them from the outset. In recent years, programmes have received a growing share of Tekes financing. They increasingly stress business-orientation, multidisciplinarity, cluster structures, business activity chains and internationalisation.

The evaluation of the technology programmes forms part of the normal operations of Tekes, and the evaluation from the viewpoint of commercialisation also works well. The programmes serve technology policy planning by producing technology reviews in their fields, and the strategic and systematic anticipation of new growth fields and technology prospects should be given more stress in the technology programmes.

An important challenge for Tekes is to promote the dissemination and utilisation of knowledge and know-how in new areas. This does not only mean promoting more extensive application of ICT in different fields, but disseminating good and efficient practices to companies. As an expert on technology development and utilisation, Tekes has an important role in promoting new business based on knowledge and know-how. Apart from project funding, its technology experts help in the preparation of projects

and fact-finding. This needs to be supported by expertise in the commercialisation and economic utilisation of research findings. Alongside consultancy services in financing, exports and other business know-how, Tekes must be able to provide SMEs with expert help in developing business based on knowledge and know-how. In this task, it is helped by its growing cooperation with Sitra, Finnvera and Finpro, among others.

The **Foundation for Finnish Inventions** supports and helps private individuals and SMEs to develop and exploit inventions. It has an especially important role in supporting the early stages of the exploitation. The aim is that as many projects as possible are later transferred for others to finance further and can be commercialised.

It is important for the further financing and commercialisation of projects to promote the networking of the Foundation for Finnish Inventions both internationally and nationally and its active cooperation with other partners in the innovation system. Apart from project funding, the Foundation for Finnish Inventions must be able to offer high-standard expertise in invention and innovation. In these tasks it is greatly helped by invention liaison officers at the employment and economic development centres.

According to an evaluation of Finnish invention and innovation, it would be important to develop the financing of invention and the exploitation of inventions, as well as services, especially private services, in support of invention. The Foundation for Finnish Inventions should also explore possibilities to develop commercial services alongside its current activities.

The **Finnish National Fund for Research and Development** (Sitra) is an independent public fund under the responsibility of the Finnish Parliament. Its operations are mainly financed through income from endowment investments and project finance. Its important role in the development of business based on knowledge and know-how has been further strengthened when public equity investment intended for the start-up and early stages was concentrated to it.

Despite the favourable development of the equity market in Finland, access to equity investments is still a problem for companies in the start-up stage or in the phase preceding it, i.e. at the seed financing stage. This is typically an area which does not interest profit-seeking private investors, because profits are uncertain or too far in the future. Business at the start-up stage often requires active long-term development, which may prevent the participation of investors committed to high yields. This is why it is important

to ensure by special public measures that the equity market functions well in respect of start-up companies.

Apart from financing, it is important to secure good regional access to services and a high standard of expertise needed in feasibility studies. Sitra has actively built networking together with universities and research institutes by establishing companies specialising in technology licensing and commercialisation. These and regional funds consolidate Sitra's role as a regional operator.

Finnish Industrial Investment Ltd is a state-owned equity investment company which primarily acts as a fund for funds. In 1998 its commitments to 20 funds amounted to nearly EUR 60 million. Eight of these funds were regional venture capital funds. The activities of Finnish Industrial Investment in turn has increased domestic private equity investment in venture capital funds. By investing in funds with different strategies, Finnish Industrial Investment can direct its funds in response to the needs of industry on a broad base, for instance to growth and internationalisation, investments and business rearrangements.

Under an amendment to the Finnish Industrial Investment Ltd Act which came into force at the beginning of 2000, the overall aim of Finnish Industrial Investment is to direct equity funding to problem areas in which the private sector does not invest sufficiently despite the positive development in the equity market. Its priority is to develop funds investing in start-up companies and strengthen their investment capital. It can also promote development in services and other new growth areas. Some action has already been taken to develop Finnish Industrial Investment, as indicated in the government programme, with an allocation of EUR 42 million included in the second supplementary budget of 1999.

Finnish Industrial Investment actively contributes to the establishment of regional venture capital funds. Together with EU structural funds, it has an important role in increasing the volume of venture capital companies and in promoting their operation.

Utilisation in regions

In addition to developing the national innovation policy in the long term, Finland also seeks to promote conditions for innovation on a regional basis. Regional development plans increasingly highlight innovation policy. The focus in regional development is on making intellectual capital, infrastructures and services locally available to users. Regional development

does not compete with national development, but instead complements it. The aim is to ensure that national and international projects and services are easily accessible to local companies and other users, and that the region can capitalise on national and international developments.

The preconditions for innovation are the same at the regional as at the national and international levels as regards both content and quality. This is a question of the development, transfer and utilisation of knowledge and know-how, the growth of intellectual capital, access to sufficient growth financing and high-standard expert services, a smoothly running infrastructure and a strong entrepreneurial spirit. In terms of regional development, it is important that conditions for innovation are also created with the help of elements acquired from other regions and even abroad through networking.

The range of partners in the innovation system has changed and developed in recent years. Alongside old operators, there are new ones who contribute to development of regional innovation processes. Higher education has been developed and expanded through the creation of a varied and comprehensive polytechnic system. The network of science parks has expanded and established its status as an active operator and contact builder. The centres of expertise instituted on the basis of regional policy legislation have just started their second period with larger programmes. More attention has also been paid to regional innovation in EU structural fund activities, which add significant international resources and good practices to regional development. A recent reform of state regional administration instituted employment and economic development centres, and regional councils have been established for regional planning. The latest reform concerned state financing: special services targeted at export companies and SMEs were concentrated into Finnvera and venture investment activities into Sitra. The main focus will continue to be on promoting a regionally comprehensive innovation network.

The first Government **programme for centres of expertise** was implemented in 1994–1998; the second term will extend to 2006. This represents a fresh approach to regional development even in international terms. The evaluation of the first programme paints a positive picture, and on the whole the programme has met expectations. During the second term, more attention will be given to active participation and commitment of companies, the development of intellectual resources and the utilisation of new know-how in the development of business in the region.

Special attention will have to be paid to strengthening cooperation between regions and closer interaction with national development projects in education and research. Interaction is needed to coordinate national and regional development and promote cooperation and division of work between regions. One important task in further action will be to develop procedures for strengthening the innovation potential outside the centres of expertise, for instance through networking and ICT.

Science parks have been building bridges between research and business for some time. In 1999 the Finnish Science Park Association FISPA had 17 members representing 1,200 companies which employed a total of 12,000 persons. The science parks have such an important role as operators and developers of the innovation systems in their regions that their multiplier effects on the long-term development and competitiveness of business are much greater than their immediate impact on employment and economy. This effect is further intensified by the fact that the science parks often work in close cooperation with centres of expertise and act as links for EU innovation centres.

The **employment and economic development centres**, which are joint efforts between three administrative sectors, now number 15. The centres house the enterprise services of the Ministry of Trade and Industry, the employment districts of the Ministry of Labour and the rural districts of the Ministry of Agriculture and Forestry, as well as the domestic units of Tekes and Finpro. The aim of the centres, together with regional councils, is to achieve a common view of the development needs and opportunities in the region and to use the resources available at the centres flexibly to achieve the stated objectives. They need to contribute to the formulation of a development strategy which genuinely develops the industrial structure in the region and in which regional and national resources support this development in a balanced way.

The capability of the employment and economic development centres to provide the expert services assigned to them was improved with the establishment of technology units, where invention liaison officers work. The technology units must be given more responsibility for regional strategic planning and for the development of inter-regional cooperation. An important support for them in this task is the guidance provided by Tekes and its expert network. They can also promote cooperation with centres of expertise and science parks on the one hand, and with universities and polytechnics on the other. This is especially important in regions where

there are no other organisations to support the activities of the employment and economic development centres.

The role of the employment and economic development centres in education and training is to purchase labour market training. The problem is inadequate matching between regional education and training provision and industrial structure, which hampers business development in the region. Another problem is a growing need to retrain persons whose vocational skills have become obsolete with the change in the industrial structure. Labour market training does not provide an adequate solution to this problem. The regional problems of vocational training must be alleviated through closer cooperation in educational planning.

The task of the **regional councils** is to develop the region and look after its interests. This means among other things that they prepare the regional development programme and coordinate the regional development measures under the competence of regional authorities. They prepare plans and programmes in cooperation with state and local authorities and with local companies and organisations. Each region also has a cooperation group which is chaired by the executive director of the region and whose secretariat is the regional council. The group deals with all development measures co-financed by the EU in different administrative sectors, with a view to ensuring that the projects are compatible with the regional objectives.

The regional council and cooperation group represent local expertise and views of different interest groups. The promotion of innovation is often a central element in the development strategies devised by the regional council, but often remain at too general a level to contribute to regional innovation processes, with the exception of the centres of expertise programme. Efficient measures entail a systematic view of the foremost problems and development needs in regional innovation. It would be important to enhance the competence of the regional councils to enable them to promote innovation in interaction with other regions and national development measures. This is a challenge they share with the centres of expertise, universities, polytechnics and employment and economic development centres. Attention should also be paid to acquiring planning help from abroad.

Between 1995 and 1999 Finland received altogether EUR 1.7 billion from **EU structural funds**, which together with national financing made 925 million in 1998. The most important of these structural funds in terms of innovation processes are the European Regional Development Fund and

the European Social Fund. In Finland the Ministry of the Interior is responsible for administering the Regional Development Fund, which also co-finances research. The Social Fund, which is administered by the Ministry of Labour, largely focuses on the development of human capital. The activities of both funds are implemented within the Objective programmes.

The structural funds are a significant resource for the development of regional innovation processes. Decisions concerning the years 2000–2006 clearly shift more responsibility to the member states, intensify both activities and administration and shift the focus towards innovation and the development of the industrial structure. As a result, it is possible to organise administration and activities in a nationally appropriate way. Other development measures needed relate to monitoring and evaluation practices, the strengthening of regional know-how structures, the matching of education and training provision and demand, and larger research and educational projects implemented jointly with other regions and national development projects.

Universities and polytechnics have extensive and varied tasks in regional development. Apart from actual education and research, they help to translate research findings into knowledge-intensive business activities. To this end they not only cooperate with other partners contributing to innovation processes in the region but also use their own networks, such as centres for continuing professional education, research and patent liaison officers. The requirement of a high international standard in university research and education also applies to their contribution to regional development with a view to creating sustainable, self-strengthening and internationally competitive innovation processes in the region.

Polytechnics have a clear duty to promote regional development and business. With co-financing from structural funds they have intensified their contacts with working life, strengthened cooperation with other polytechnics and developed various service products for local companies. The foremost task for polytechnics is, however, to train professionals with advanced competencies and to upgrade their knowledge and skills in response to regional needs.

Regional equity investment. It is the intention that responsibility for the growth financing of companies will gradually be transferred from the public sector to the private sector. Financing of start-up companies is seen to require a more permanent public financial arrangement. Regional financing for companies in the seed and start-up phases has been given over

to Sitra. The newly established fund management companies administer the investments of regional venture capital funds. The purpose of this arrangement is to safeguard regional initiative and create conditions for sufficiently large joint investments and develop the investment know-how of regional fund management companies.

Overall, the development of regional innovation processes in Finland is developing in the right direction. Many regions have also begun to have solid proof of the effectiveness of the activities. The level of knowledge and know-how has risen, regional cooperation and commitment are stronger, business development has got off to a good start, and new jobs have been created. But there is still a great deal to do. The supply of private services which support innovation has not developed as favourably in Finland as elsewhere. Another shortcoming concerns evaluation. Evaluation relating to regional innovation processes is diffuse and varies in quality. More efficient ways must be found to make expertise developed at the national and international levels available to regional projects.

Utilisation in companies

Where commercialisation is concerned, companies are the primary users of research findings and know-how produced by the public and private sectors. Knowledge and know-how are transferred to and cumulate in companies as a result of various and complicated processes. In companies they are utilised in the form of different innovations which the companies offer to the market. It is vital for both the competitiveness of companies and society to promote and intensify innovation processes. This has particular significance because in this way the resources invested in research and education at the initial stage return to society in full.

The knowledge-intensity of companies has grown side by side with networking. Networking enables companies to concentrate on their core competencies and to outsource other knowledge and know-how. The foremost partners in the networks are contractors, customers, universities and research institutes, and often even competitors. In this way networking companies can increase and master the knowledge and know-how they need.

Traditional professional skills are often not enough for this operation model. It demands skills in operating in flat, self-steering expert organisations, which are characterised by the integration of external and internal activities and horizontal cooperation. Labour market organisations have an important role in the development of networking.

These development trends are typical of high-tech business in particular, but the overall trend is the same in other companies as well. They have high-standard knowledge and know-how and, instead of carrying out their own R&D, their development often focuses on active application of research findings produced outside the enterprise, on the utilisation of the technology of their subcontractors and equipment manufacturers, and on know-how developed through their own activities or on service and product design. Innovation is always demanding and requires large-scale management of knowledge and know-how as well as cooperation and interaction with other producers and users of knowledge and technology.

A well-functioning financing market provides the basic conditions conducive to the growth and development of companies. However, the insecurity and demands involved in calculating the financial risks and returns make it difficult for innovative companies to finance their activities with loan capital, especially in knowledge-intensive fields where investments are often intangible and return on capital is often based on expected earnings. This is why companies based on knowledge and know-how need access to equity funding. It is the task of the public sector to support business and investment culture based on long-term thinking and to enable innovative companies to grow and develop by filling in the gaps in the operations of the financing market.

The relatively small number of growth companies in Finland cannot be explained by lack of ideas or sectoral expertise. Shortcomings have been identified especially in the protection of intellectual property, marketing know-how, familiarity with alternative forms of financing, and commercialisation. More generally this means a need to enhance the business know-how of small companies. Inadequate business know-how may thwart the commercialisation of knowledge and know-how as well as the commercial success of many promising projects. Another obstacle is Finns' typically cautious attitude to entrepreneurship, earnings and the risk-taking involved in rapid growth. This is why the criteria for public subsidies, aid and loans should include the growth potential of the company involved.

The inadequate mobility of intellectual capital across sectors undermines the dissemination of sectoral knowledge and know-how across sectoral boundaries. This challenge concerns the dissemination and utilisation of ICT know-how in more traditional industries and services. One way to promote mobility is to devise incentive systems in the labour market.

The challenge of utilisation

The five development trends discussed in section 2 mean a major challenge to the national innovation system as a whole. The development of conditions conducive to the utilisation of knowledge and know-how concerns both public sector support and service organisations as well as private sector and individual capabilities to utilise knowledge and know-how. Efficient dissemination of knowledge and know-how requires close cooperation between many different operators and levels, from international cooperation to the level of individuals. It is a demanding task since it involves making knowledge and know-how produced both in Finland and abroad available to users.

For technology and education policy planning it is important to be able to put companies' estimates of the growth prospects in different technology sectors and industrial branches and of development of needs to efficient use. This is why it is important to further strengthen systematic anticipation of growth areas and technology foresight.

As regards commercial utilisation, companies are the primary users of research findings and know-how produced by the public and private sectors. Efficient commercialisation of technological know-how entails, however, that the business know-how of small companies in particular is developed through training and different expert services.

One important requisite for the growth of companies based on knowledge and know-how is a smoothly functioning financing market. Access to equity financing must be secured by public means, especially for start-up companies. It is also important to secure a high standard of expert services needed in feasibility studies and other business surveys.

Alongside long-term development of national innovation policy, efforts have also been made to promote conditions for innovation on a regional basis. In regional development it is important to build intellectual capital, infrastructures and services which need to be available close to their users. The intention is to make sure that national and international projects and services are easily accessible by companies and other users in the region and that the capacity of the region to utilise national and international development is strengthened.

3.3 Development of research funding

The need to develop research funding depends on the objectives set for R&D at a given time. The conscious effort to promote knowledge-intensive business and to develop Finland widely as a knowledge-based society is also seen in the rapid growth in research funding during the 1990s. At the same time, there have been many changes in the research funding structure. At the most general level this change is seen in the following table:

Sources of research funding in 1991 and 1998, EUR million and per cent

	Companies		Public sector		Foreign countries		Total
1991	921	54 %	768	45 %	22	1 %	1 711 100 %
1998	2 085	62 %	1 099	33 %	171	5 %	3 355 100 %

In 1987 the Science and Technology Policy Council recommended that research funding should be raised so that the public sector/private sector ratio of 40:60 could be maintained. The table shows that the situation has fluctuated and that in the 1990s there was a clear trend towards decreasing public sector shares in financing. This has happened despite the decision (1996) to raise the level of public research funding by a total of EUR 250 million over the period 1997–1999. A new feature in the overall picture is the increase in foreign financing. Most of its growth and volume is in the form of enterprise-to-enterprise financing. The amount of EU research financing used in Finland in 1998 was EUR 55 million.

Companies, especially in the electric and electronics field, increased their R&D input rapidly in the 1990s. Since 1995 the annual growth has been between EUR 250 and 300 million. Private research funding is expected to continue growing for a few years, but to eventually slow down for reasons relating to the shortage of intellectual resources for expert jobs. The annual increase in funding other than public research funding will probably stay over EUR 170 million during the period under review, 2000–2004. The overall development of national research funding and its GDP share primarily depend on the development of corporate research investments, so large are the differences in volume between the public and private sectors.

From time to time it has been debated whether the development of research funding has been balanced. Research in Finland has developed to

the extent that now that research financing is three per cent of the GDP, there is no longer any justification to keep public sector financing at 40 per cent. On the other hand, it is clear that the public sector must be able to take care of its duty to develop a knowledge-based society and secure knowledge-intensive growth in an appropriate way.

The present situation is very challenging to the public sector in that its field of operation in the promotion of science, technology and innovation has grown and become more demanding. This review has identified and analysed several new challenges and development needs. *The public sector must be able to implement special development measures simultaneously in five different directions. Measures are needed (1) to develop conditions favourable to the information industries, (2) to support social, economic and cultural development, (3) to identify new growth areas, (4) to disseminate knowledge and know-how and promote their wide-scale utilisation, and (5) to consolidate the knowledge base.* Research, postgraduate and other education and the utilisation of knowledge thus created in the form of economic, social and cultural innovations are at the heart of development.

The Science and Technology Policy Council sees that successful response to these challenges requires an increase in public resources. Private and public input are targeted at different parts of the innovation system. However, the performance of the system depends on how well it operates as a whole. Activities under the responsibility of the public sector which demand special attention in terms of financing include the education and training provision as a whole, basic research and the dissemination and utilisation of knowledge through the development of the services which support it. The response to the challenges does not require new organisations. It is primarily a question of improving the organisations operating within R&D to meet the need for developing the innovation system as a whole. Thus the resource increase would not be allocated to R&D alone, but more widely to the development of all activities in the national innovation system.

An increase in public research funding also encourages the private sector to develop its financing. Well quantified and targeted public allocation boosts private investments in R&D carried out in Finland. From the point of view of the business sector, the key question is what kind of conditions is the public sector able to offer for the growth and development of corporate R&D in Finland. Without a determined and balancing input by the public sector, the possibilities of the business sector to invest in innovative activities will become weaker.

The public sector has a central role in social and cultural development and in improving citizens' capabilities and opportunities. It enables the opportunities inherent in the growth of knowledge and know-how, with their positive employment effects, to be exploited more efficiently, and different alternative development lines to be assessed better than before. The development of basic education and lifelong learning is vital in this respect.

Because of the challenges discussed in this review and the marked growth in private and foreign research funding, which is predicted to continue, *government research funding needs to develop from 2001 to 2004 according to the next table, at a rate corresponding to the estimated GDP growth. According to the present growth estimates, this would mean an annual increase of some EUR 50 million.* This is a question of maintaining the performance and competitiveness of the Finnish innovation system and securing an internal balance in public research funding. Together with the estimated growth in other research funding, the increases proposed lead to the following development in the national research input:

Development of research funding 2001–2004
(EUR at the 1999 monetary value)

	1999	2000	2001	2002	2003	2004
GDP, billion EUR (+3 1/2 %/yr.)	120	124	129	133	138	143
Public funding, billion EUR	1.27	1.28	1.34	1.39	1.44	1.49
Public funding, % x GDP	1.06	1.03	1.04	1.04	1.04	1.04
R&D funding, total, billion EUR	3.75	4.00	4.29	4.56	4.81	5.05
R&D funding, total, % x GDP	3.1	3.2	3.3	3.4	3.5	3.5

The public sector must be able, within its general financing capacity, to ensure an appropriate development of research funding. According to the Science and Technology Policy Council, the cumulative increases over the period 2001–2004, as presented in the table, are necessary and proportionate to the public sector duties in science, technology and innovation policies, to the development of private sector funding and to the

capacity of the state finances. The national economy is improved by means of activities which create new knowledge and new operational structures, which in turn also creates better conditions for the operations of the public sector.

As the Council sees it, the increase in public sector research funding must be mainly distributed to the science and technology administration according to the following principles.

In the administrative field of the *Ministry of Education*, the needed increases relate to university and polytechnic core funding and the commitments of the Academy of Finland. As regards core funding, the programme for additional and retraining relating to information industries, together with eventual further programmes, should be included in normal financing, as far as basic education is concerned. This educational sector has expanded permanently. The development measures already taken in researcher training must be continued and also intensified. In new knowledge-intensive growth fields it is necessary to launch special measures in higher education. These include a large-scale development of business know-how, entrepreneurship and expert services relating to innovation. Polytechnics have a special task to develop their activities as part of the regionally comprehensive innovation network.

The Science and Technology Policy Council recommends that, with a view to encouraging structural change, the core funding of **universities** be increased by a sum corresponding to their own reallocation of freed operations funds. If universities can reallocate the recommended three per cent share of the 1999 core funding level to new targets by 2002, this additional increase in public funding would amount to nearly EUR 35 million in all.

As regards universities, it has already been noted earlier that core funding represents a relatively small proportion of the state budget and that the price of research person-year is low in international terms. Since the statistical estimate for the share of research in university core funding is 30 per cent, excluding some appropriations entered in full, increasing research funding by a given sum will in inverse ratio require an over threefold increase in operational funds. In this way even substantial increases in operation funding would not mean corresponding increases in the statistical university research funding.

The two most urgent increases needed by the **Academy of Finland** concern an additional commitment required for the overhead extra in research funding in 2001, and the need to expand the programme for centres

of excellence from the beginning of 2002. The overhead extra will require an increase of some EUR 15 million. As for the centres of excellence programme, the Academy has proposed that its commitments be increased by an once-and-for-all sum of EUR 35 million. The continuation of the programme will require a corresponding increase every three years. Other development tasks for the Academy are to create conditions for new growth areas together with Tekes and universities. In this they must make the most of international financing cooperation and other opportunities inherent in the globalisation process. The Academy and Tekes should also intensify their cooperation in the development of cluster-based activities together with sectoral ministries, as proposed below.

The main development objects in the administrative field of *the Ministry of Trade and Industry* are Tekes and the basic funding of VTT, which has not developed in keeping with the volume of activities. The increase in the basic funding should be EUR 2-3 million a year. Tekes has grown and developed rapidly in the 1990s. Today it is facing the same challenge as the public sector in general of developing society and the economy on a sustainable basis. In the opinion of the Science and Technology Policy Council it is more expedient to increase Tekes' resources than to establish new organisations for the purpose. The challenges facing Tekes primarily relate to further reinforcing strong technology fields, identifying new growth areas and promoting their development, as well as building up and supplying high-standard innovation and business management services. Another challenge relates to the dissemination and utilisation of research findings and technological progress: to promote these on a wide scale jointly with partners operating within the national and regional innovations systems. Thirdly, the significant role Tekes already plays in financing the cluster programmes and developing pilot networks must be further strengthened.

The clearest increase in *sectoral administration* is a rise of EUR 2.5 million in 2001 in the basic funding of the centre of expertise programme allocated by the Ministry of the Interior. With a view to enhancing environmental know-how, environmental cluster research must be increased in keeping with the government programme. In other respects, the Council stresses the need to conduct an independent evaluation of the uncommitted funds at the disposal of ministries as part of the systematic evaluation of the research system and its financing.

The Council also stresses, as it did in its previous review, the importance of promoting R&D relating to industrial clusters in Finland within sectoral

administration. This may comprise continuing, expanding or supplementing ongoing cluster programmes, launching new ones or applying the efficient cooperation mechanism developed within clusters to other than industrial clusters through cooperative research programmes.

The first cluster programmes were launched within the programme for increases in government research funding launched in autumn 1996, which provided for a permanent rise in the level of government research funding. In this connection, the Science and Technology Policy Council resorted to an exceptional procedure in nominating the industrial clusters to be strengthened by means of additional funding allocated through the ministries responsible for the clusters. There is no longer any need for such procedure. Experience shows that the cooperation mechanisms are already so advanced that the selection and launching of clusters can be subjected to the same competition-based financing procedures as are applied to the projects implemented within them. In practice this requires closer cooperation between the sectoral ministries and the two financing organisations, Tekes and the Academy of Finland, from the planning stage onwards. It will also help the ministries to build a cooperation network with research organisations, companies and other partners. While this will intensify both the production and utilisation of new knowledge and know-how, more attention will be paid to the quality and relevance of research. It is the task of the Science and Technology Policy Council to monitor the cluster activities and issue development recommendations when needed.

The Science and Technology Policy Council proposes that government research funding be increased cumulatively according to the following table. The figures indicate appropriations, with the exception of the commitments in the case of the Academy of Finland in the Ministry of Education sector and Tekes in the Ministry of Trade and Industry sector.

Cumulative increase in government research funding 2001–2004
(EUR million at the 1999 monetary value)

	2001	2002	2003	2004
Ministry of Education	31	56	76	96
Ministry of Trade and Industry	24	46	71	96
Other administrative fields	3	5	8	10
Growth from 2000, total	58	107	155	202

In its previous review the Science and Technology Policy Council stressed the importance of evaluating research financing, noting that rapid growth requires close monitoring and performance evaluation. As a result, an independent evaluation group was invited to assess the impact of the programme for increases in government research funding implemented between 1997 and 1999. In addition to the points made in section 2.2, the evaluation group notes in its interim statement that there are a number of new participants in R&D projects. Finnish researcher stock has evolved in terms of both quantity and quality. For the benefits of financing to be increased, the Finnish innovation system must be developed and honed further. The expert group will propose more detailed corrective measures after it has compiled a sufficient information base. The weaknesses appear to relate to know-how, seed funding and companies which fall outside the system. All in all, the additional funding is expected to improve Finland's success in international competition in both science and technology.

In the opinion of the Council, the financing programme proposed here for the period 2001–2004 will demand careful monitoring and impact analysis in support of future policy lines and development measures.

4

Recommendations

In the following, the Science and Technology Policy Council presents its opinions and recommendations for the development of the innovation system in a sustainable manner in future. The recommendations concerning financing have been presented in section 3.3.

In this review the Council has focused on the tasks and challenges of the public sector in conditions of global change. Global change influences society and the economy in many ways, both nationally and regionally. It tends to highlight the importance of public sector measures. Within the Council's competence – the promotion of science, technology and innovation – the public sector is faced with demanding challenges, notably to maintain an economically stable operational environment conducive to innovation, develop institutional arrangements in support of innovation, provide the high-standard infrastructures needed for education and research, and strengthen intellectual resources. In addition to such general measures, the challenges relate to know-how in the fields of financing and administration, marketing and technology, especially as regards SMEs. The public sector has an important task in promoting social and cultural development and the construction of the Finnish information society. Good cooperation

between the public and private sectors and the further strengthening of international cooperation must also be maintained.

- The national innovation system must be further developed on a wide scale in cooperation between the public and private sectors. One important consideration, alongside of quality, efficiency and relevance, is the impact of activities and impact analysis. The internationalisation of the innovation system must be continued.

Challenges for the public sector

In section 2, the Science and Technology Policy Council discussed the challenges and tasks in which the public sector plays an important part with regard to overall development. Securing conditions for the development of the information industry is an area in which the public and private sectors have long traditions of cooperation; this is also seen in the total input into the development of this area. Its future development in Finland will continue to demand public sector measures. It is especially important to strengthen the position of women.

- It is necessary to continue promoting conditions conducive to the development of the information industry and the systematic use of the development potential in software and content industries. Special attention must be paid to enhancing intellectual resources and mathematical and scientific knowledge.

One central task for sectoral policies is to support social, economic and cultural development. The overall development of the innovation system will only succeed through good interaction with other sectors. It is also important to enhance cooperation between sectors. Education and training, research and technological development are strategic resources for all policy sectors.

- Measures geared to increase knowledge and know-how and their utilisation must be continued in all sectors, with a growing emphasis on cooperation. Within regional development and employment policy, this consideration should be particularly prominent. The cooperation model created in cluster networks offers new opportunities for general development of sectoral activities.

Present strength areas alone do not provide a sufficiently fertile breeding ground for future development. The knowledge base accrued must be actively used to identify new growth areas and create conditions for their development. Especially interesting are rapidly developing fields which have positive effects on employment or on the development of other fields.

- Public sector organisations and the private sector need to make a joint effort to identify new growth areas and promote their systematic development. Strengthening the overall conditions for business requires additionally the development of equity investment and business management, and joint measures with a view to strengthening entrepreneurship and enterprise culture in Finland.

Finland has a great deal of high-standard knowledge and know-how, and their efficient dissemination to other branches or to regions involves a significant development potential. This must be used to promote regional development, among others. ICT have a key role both as a means of making knowledge and know-how available to users and as highly applicable technologies in other fields.

- The dissemination of accrued knowledge and know-how over sectoral and branch borders must be intensified for instance through measures promoting the mobility of personnel and innovation services available to companies. One important task is to develop a regionally comprehensive innovation network.

It is impossible to respond to these challenges if the knowledge base does not function well. It is specifically a task for the public sector to strengthen the base to meet future needs. This involves continuing and extensive development of education and research and input into top-standard know-how and internationalisation and capitalising on globalisation, as well as a number of special measures, such as enhancing mathematical and scientific knowledge and, alongside it, humanities, social science and business know-how.

- The public sector must be able to continuously develop and strengthen education and research in Finland. This will secure basic conditions for social, economic and cultural development for the benefit of the individual and society as a whole. This task is especially demanding in view of the rapid growth in the knowledge-intensive economy.

Development of knowledge and know-how

The significance of education and training for the development of the national innovation system has been growing rapidly. In the domain of mathematical and scientific knowledge, it has been necessary to examine development needs from primary education upwards. The same applies to knowledge and skills needed by all citizens in the information society. The central role of education is also manifested in the need to propose increases in the resources of all educational levels, although Finnish educational input has been high for a longer time. The development measures needed are correspondingly comprehensive. The evaluation of the quality and relevance of education must be further developed.

- The overall level of education needs to be raised continually in Finland through qualitative and quantitative development. The growing need for competent teachers must be satisfied. The matching of education and working life must be improved with regard to secondary vocational education and higher education. The changing qualification needs of the adult population must be met according to the principles of lifelong learning and with relevant input. Educational structures must also be developed.
- This general development must be supplemented by flexible special measures. The most urgent of these is to increase basic mathematical and scientific knowledge and to expand the recruitment base for higher education. Training and education in support of entrepreneurship must be increased at all levels of education.

Basic research and postgraduate education are important tasks under the responsibility of the public sector in Finland, alongside overall educational development. Developing the basic prerequisites for higher education institutions, strengthening the Academy of Finland and promoting cooperation both within the public research system and with the private sector demand both resources and other development measures. It is also up to the public sector to provide the infrastructure, basic knowledge and skills and competent professionals. One important responsibility for the public sector is to make sufficient intellectual resources available for demanding expert tasks. High-standard research must be supported regardless of the discipline. On the whole, the capacity of Finnish universities and the Academy of Finland for responding to the need for increasing basic research

and postgraduate education and other development challenges is clearly dependent on the financing recommendations presented in 3.3.

- The basic prerequisites of university research and postgraduate education must be improved with a view to further strengthening research environments and developing their material resources. It is the task of the Academy to continue to intensify and expand its measures for increasing high-standard research and expertise in Finland. Finland must be prepared to respond to transitions in the global economy, culture and science, for instance by means of science watch and through improved cooperation between all the operators in the research system.

One of the permanent tasks of the Science and Technology Policy Council is to develop and monitor ministries' sectoral research. Appendix 3 contains the Council's recommendations on sectoral research adopted on 4 February 1999, which are still valid. The intention is to strengthen the scientific knowledge base of the sectors and its use in the development of sectoral policies. General development measures concerning sectoral research are examined from another perspective in connection with the overall reform of state administration. Cooperation between the Council and this reform process needs to be continued.

- Within sectoral research, the uncommitted research funds at the disposal of ministries must be evaluated – as the last significant part of the public research system still outside systematic evaluation. Cluster-based activities must be further developed and the model of networking created within it must be applied to other research programmes. The structural development of sectoral research must be continued as part of the overall public management reform.

Technology development has been a clear priority in the public sector throughout the 1990s. This has contributed to the rapid development of industry, especially the information industry. Tekes has a central role in this, together with its customer companies, research institutes and universities. Apart from this positive development, the most important challenges facing Tekes relate to new openings and activities and further intensification of international technology cooperation. By constantly developing its financing procedures, Tekes can efficiently influence the quality and volume of corporate R&D towards challenging and long-term projects and cooperation.

- Tekes must continue to promote the spread of knowledge-intensive growth into new areas and intensify its measures in order to secure conditions for the growth of domestic corporate R&D. It must also be able to expand its own competence in response to new challenges.

Utilisation of knowledge and know-how

Determined efforts to increase knowledge and know-how have created new opportunities for their utilisation in business activities and in society as a whole. It is necessary to intensify the utilisation of knowledge produced both abroad and in Finland with a view to distributing the positive effects of growing research and education to benefit society and citizens as widely as possible. The key factor in this is good cooperation between producers and users of knowledge and know-how. Alongside national measures, attention must increasingly be paid to enhancing conditions for regional development. Networking continues to be an important means to producing good results.

- Tekes also has an important role in promoting the dissemination and utilisation of knowledge and know-how. At the national level this is a question of developing high-standard expert services and promoting the dissemination of knowledge and know-how in cooperation with Sitra, Finnvera and Finpro, among others. The expert services of the Foundation for Finnish Inventions need to be developed with a view to promoting invention and innovation. Access to venture capital for start-up companies must be improved by joint measures of public and private equity investors.

It is important to intensify regional measures both to step up regional development and to utilise the innovation potential of the whole country as efficiently as possible. General measures needed to this end are to strengthen interaction between the national and regional levels, to develop a regionally comprehensive innovation network and to improve cooperation between regions and between partners operating in them. The new centre of expertise programme has an important role in supporting projects of international standard and their utilisation.

- Polytechnics must be developed into knowledge and know-how centres to enable them to make a more significant input into innovation in their regions. At the same time measures must be taken to increase

cooperation between universities and polytechnics in regional development. EU structural funds constitute an important resource which the regions should systematically use to increase knowledge and know-how and promote their utilisation on a large scale. Employment and economic development centres play an important part in regional development; their activities and resources must be systematically channelled so as to increasingly promote development and creation.

The commercialisation of knowledge and know-how mainly takes place in companies. It is the task of the public sector to strengthen general conditions for corporate innovation processes. In traditional industries and services, the development of knowledge and know-how often focuses on the application of research findings produced outside the enterprise and on other know-how development, instead of companies' own R&D. This requires extensive mastery of knowledge and know-how and cooperation and interaction between producers and users of knowledge and technology.

There are few companies in Finland which aim at rapid growth. There are shortcomings in companies' marketing and other business know-how. Knowledge relating to the protection of intellectual property must also be increased.

- Companies must improve know-how relating to the management of their own innovation processes and the economic exploitation of innovations for example through education and training. It is for the public sector to increase the supply of expert services and know-how by developing business training and applied business research. The growth potential of companies should be one of the fundamental criteria for public promotion measures.

Appendix 1

Science and Technology Policy Council 1996–1999

The fourth term of the Science and Technology Policy Council of Finland began on 1 March 1996 and ended on 28 February 1999. During this time, the Council convened twelve times. On 9 December 1998 it held a joint meeting with the Economic Council on the theme 'The challenge of the labour market for the innovation- and knowledge-based economy'. The science policy subcommittee convened 23 times and the technology policy subcommittee 21 times.

The implementation of the programme for increases in government research funding adopted by the Government in autumn 1996 was an important focus in the Council's work during the whole term. The programme was prepared and adopted in autumn and was included in the Council's review "Finland: A knowledge-based society" published on 17 December 1996. The Council has worked in cooperation with the Ministry of Finance and other ministries in implementing the programme according to the state budget from 1997 to 1999. Parliament has been informed of the implementation. On 10 March 1997, the Council took initiative for the monitoring and evaluation of the additional financing programme. An independent expert group was invited for the purpose by a joint decision of the Ministry of Education and the Ministry of Trade and Industry on 18 December 1997. Mr Aatto Prihti, President of Sitra, was invited to chair the group. The interim statement of the group is attached as Appendix 2.

The Council adopted a memorandum of research funding for 2000–2004 at its meeting on 4 February 1999. It has been used in the preparation of this review.

The development of sectoral research is one of the permanent tasks of the Council. Opinions concerning it were adopted on 3 June 1997 and 4 February 1999, the latter had been prepared by a steering group selected by the Council from amongst its members. Before this, the Ministerial Group for Administrative Reform had discussed the development of sectoral research. Appendix 3 contains the conclusions and recommendations of the steering group.

Important science and technology policy issues discussed by the Council were the preparation of Finland's EU research strategy in 1996, EU research and innovation policy and Finland's preparation for the EU Presidency in 1999.

Another theme which gained importance during the term was the development of intellectual resources. It was included as a permanent element in the Council's work programme. The Council held a meeting around this theme on 6 October 1998.

The Council dealt with the development of regional innovation processes for the first time on 1 June 1998, when it adopted a memorandum on the subject. This theme has been on the agenda since then.

Appendix 2

Interim statement of the expert group 10 December 1999

According to the allocation for of the additional research funding adopted by the Council three years ago, a special aim was to intensify the functioning of the innovation system for the benefit of the economy, business and employment. Most of the funding has been channelled for basic research and technology development through the Academy of Finland and the National Technology Agency Tekes. Additional targeted funding has also been allocated to the Technical Research Centre and universities. The third funding object is R&D projects which support the development of industrial clusters in Finland and which are jointly implemented by sectoral ministries, the technology and science administration and companies. The overall increase in the level of research funding was EUR 250 million at the end of the programme.

Seven research projects, to be completed by spring 2000, were launched to support the impact analysis. Preliminary results indicate that the programme has had a positive effect on the economy and on business. The expert group will examine the impact in more detail in its final report, which will be published in a year's time, although most of the effects of the programme are expected to materialise after the evaluation period has ended.

The increase in public input has encouraged companies to increase their own R&D activity. Thus, the target research input set for 1999, 2.9 per cent of the GDP, was already achieved, and even exceeded, in 1998. R&D projects have attracted a number of new partners. The Finnish researcher stock has strengthened both in number and in quality. New, varied cooperation has emerged between the administrative fields, domestic and foreign research institutes and financiers.

With a view to increasing the benefits of the funding, the Finnish innovation system must be further developed and honed. As regards shortcomings, the expert group will propose more detailed measures after it has compiled a sufficient information base. At the moment the main shortcomings appear to relate to commercial know-how, seed funding and companies which fall outside the system.

All in all, the additional research funding is expected to promote Finland's success in international competition in the fields of both science and technology.

Aatto Prihti
Chair of the expert group
President, Sitra

Appendix 3

Science and Technology Policy Council on 4 February 1999

Development of sectoral research

Conclusions and recommendations

The development of sectoral research is an important element in the knowledge-based society, and linked to the overall development of the national research system. The general model proposed by the Science and Technology Policy Council for sectoral research is still a useful tool for steering development measures, which must be targeted at both networking and structural development. The most important characteristic of sectoral research is varied, relevant and high-standard activity. Like today research institutes may in the future have other tasks besides research. Internationalisation and international cooperation are also important for the development of sectoral research.

Functional development of institutions

The conclusions and recommendations concern either development within one research institute or research institutes in general. Recommendations relating to designated institutes or groups of institutes belong to matters to be further studied.

Institutes must pay more attention to the relevance and impact of their activities. The means to this end include possible modification of their mission and the development of activities in a more customer/user-driven direction.

Sectoral research institutes are also often important for purely scientific reasons besides immediate applications. The institutes can develop important research fields in a way which would not be possible in the academic environment, which is divided into educational programmes and disciplines.

The institutes' organisations and the definition of their missions should be clear and transparent. Modification is especially needed in the organisation of administrative and official tasks, including inspection. A natural placement must be found for tasks eventually to be transferred from the institutes. A corresponding outsourcing principle must also be applied to the institutes' other tasks where applicable.

Horizontal research cooperation must be improved within the research system by such measures as joint and part-time posts, personnel exchanges, two-way cooperation in researcher and other training and further development of the

centres of excellence network. It is a task for the financiers to strengthen horizontal cooperation further.

At the regional level, measures should be taken to put local laboratory and other research resources to the most efficient use possible. Kuopio, Oulu and the Helsinki Biomedicum are good examples of solutions made to this effect.

Operational recommendations

Ministries must further develop both their own activities and the activities of the institutes they steer by target outcome according to the general model of sectoral research. This must be done in a way which ensures a balanced development of competition and cooperation factors. They can support this by opening to domestic and international 'research markets' and seeking consciously to prevent the emergence of monopolies in the research system.

For the same purpose, Ministries and institutes should together constantly diversify their interfaces, as well as the use of funds and financing structures.

For ministries there is no one 'right' procedure for developing research and its utilisation as a strategic resource within the administrative sector. It is, however, useful to exploit the experience gained by other administrative sectors in the development of activities and organisation. The Ministries of Agriculture and Forestry, of Transport and Communications, of Trade and Industry, of Social Affairs and Health and of the Environment have renewed their administration. The solutions made by them can be used by other ministries where applicable. The Ministry of Agriculture and Forestry must explore possibilities to further simplify the institutional structure in its administrative sector.

The Ministry of Education must further clarify the role of universities and polytechnics in sectoral research and steer them by target outcome towards closer cooperation in sectoral research.

Cluster-based cooperation must be strengthened for its positive impact on networking, among other reasons: it promotes mutual interaction of research institutes, universities and business. Cluster-based cooperation also provides a natural way to strengthen the contacts of the financing organisations, the Academy of Finland and Tekes with research institutes.

In the course of the 1990s, evaluation has emerged as routine element in sectoral research. At this point there is no need for a general recommendation concerning performance or organisational evaluations. On the other hand, it appears necessary for the Ministry of Social Affairs and Health to evaluate its EVO funding now that the new financing system has been in use for two

years and the extent of these discretionary funds ought to be reviewed in view of their future quantification.

Further studies

Sectoral research institutes and universities must carry on their research and educational cooperation especially in social and economic sciences, agriculture and forestry, and geology. It is important to find out overlapping and improve the division of work in these sectors.

A separate project must be undertaken to ascertain development needs in social science research and relevant sectoral research institutes and their eventual reorganisation. This field is gaining more and more weight. It is important to determine what form of organisation gives the best response to the ever demanding research challenges.

The role and missions of R&D centres must be re-examined after they have been evaluated and they have been assigned eventual new tasks in connection with the overall administrative reform. One question to be studied is the relationship between the Finnish Environment Institute, the Institute of Marine Research and the Meteorological Institute. The study must also ascertain the need and viability of developing these institutes structurally across administrative boundaries.

Science and Technology Policy Council 1 January 2000

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